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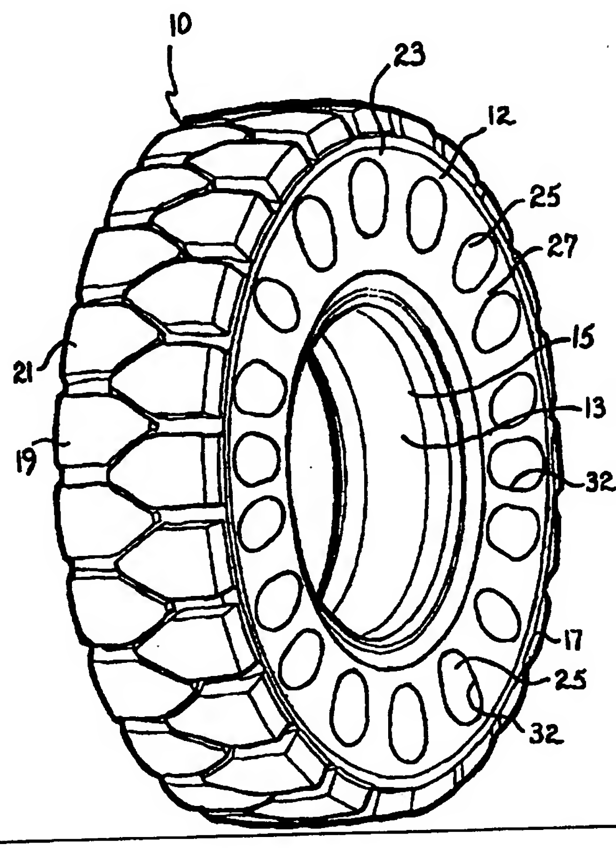
(54) Title: GROUND-ENGAGING STRUCTURE

(57) Abstract

A cyclically movable ground-engaging structure such as a tyre (10). The tyre (10) comprises a resiliently deformable body (12) having provided therein a plurality of cavities (25) each bounded by a cavity wall (32). The cavities (25) are arranged to assume a cross-sectional configuration upon resilient deformation of the body under normal static load conditions wherein said configuration inhibits formation of zones of high stress concentration at the cavity walls (32). The cross-sectional configuration assumed by each of the cavities (32) upon the resilient deformation of the body may be a closed curve. The configuration of the cavities inhibits deformation of the cavity walls (32) to an extent which would allow wall sections thereof to come into contact one with another. In this way, deformation of the cavity walls (32) to the extent where a tight radius of curvature is formed therein is inhibited.



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"Ground-Engaging Structure"

Technical Field

This invention relates to a cyclically movable ground-engaging structure for providing cushioning on an engaged ground surface. The ground-engaging structure may, for example, comprise a tyre for a wheel or a ground-contacting structure for an endless track. More particularly, the invention relates to such ground-engaging structures which are of non-pneumatic character.

Background of the Invention

There have been various proposals for non-pneumatic tyres for vehicles, including one-piece tyres and composite tyres assembled from a plurality of tyre segments. Examples of such tyres are disclosed in US 1365539 (Pepple), US 1414252 (Brubaker), US 1487920 (Dawson), US 1570048 (Dickensheet), US 5139066 (Jarman), and AU 502409 (Bayer). The proposals typically comprise a tyre having an annular body formed of elastomeric material such as rubber, and laterally extending cavities formed in the annular body and opening onto the sides thereof. The cavities are intended to provide the tyre with sufficient resilience for a cushioned ride.

Such proposals, in most cases, seek to provide a compromise between solid tyres which while not susceptible to puncturing do provide a harsh ride, and pneumatic tyres which while providing cushioning for a comfortable ride are susceptible to puncturing.

With such proposals, the tyre generally requires a considerable amount of elastomeric material in order to have the required load-carrying capacity and durability. This has several disadvantag s, one relating to the cost of production of the tyre becaus of the quantity of elastomeric material required.

Further, the amount of lastom ric material can be prejudicial to th cushioning charact ristics of th tyre.

There is therefore a need to optimise the configuration of the cavities in the body of the tyre with a view to minimising the amount of elastomeric material employed for a given load-carrying capacity, while providing a tyre which is durable and which offers sufficient cushioning for a comfortable ride.

In the proposals referred to above, the configurations of the cavities have varied greatly from simple circular apertures such as proposed in Dickensheet and Dawson, to more complex shapes such as proposed in Pepple and Bayer.

The proposals have not, however, provided non-pneumatic tyres which are altogether satisfactory. A typical problem is that where such a tyre has sufficiently resilience to provide a cushioned ride there is a tendency under normal working loads for the cavities to deform to an extent which creates zones of high stress concentration at the cavity walls. These zones of high stress concentration arise from formation of areas having tight radii of curvature in the walls of the deformed cavities. The zones of high stress concentration are cyclically applied during rotation of the tyre, resulting in generation of heat which can lead to degradation of the tyre. Further, where the tyre is also subjected to high loadings (such as in acceleration or braking) the cavities may deform to such an extent that sections of the wall of each deforming cavity are forced into contact with one anther. Rotation of the tyre causes the contacting cavity wall sections to rub against each other which results in generation of further heat.

problem

This problem is even likely to exist in non-pneumatic tyres having cavities which are circular in cross-section. The problem will be further explained with reference to Figs. 1 and 2 of the accompanying drawings which are schematic fragmentary side views illustrating a non-pneumatic tyre 1 comprising a body 2 of resilient material such as rubber formed with a plurality of circumferentially spaced cavities 3 which xt nd completely through the body in the transverse

direction from on sid wall 4 t the other sid wall. Each cavity 3 is bound d by a cavity wall 5. In Fig. 1, the tyre 1 is illustrat d in an unloaded condition in which the cavities 3 are of circular cross-section. In Fig. 2, the tyre 1 is illustrated in a condition in which it is deforming under a static load, resulting in the formation of zones 6 each having a tight radius of curvature between two sections 7, 8 of the cavity wall 5 which are urged into opposing relationship. The zones 6 at which there are tight radii of curvature in the cavity wall are applied cyclically as the tyre rotates and result in the generation of heat. If the tyre is subjected to a high loading (which is not shown) in addition to the static loading, it may deform to an extent that the opposed cavity wall sections 7, 8 adjacent one of the zones 6 are forced into contact with each other. Friction between the contracting cavity wall sections 7, 8 will generate further heat which will hasten degradation of the tyre.

It would be advantageous to provide a non-pneumatic tyre which overcomes, or at least reduces the effect of the problem outlined in relation to the earlier proposals mentioned above for non-pneumatic tyres.

Summary of the Invention

The present invention provides a cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a cavity bounded by a cavity wall, the cavity being arranged to assume a cross-sectional configuration upon resilient deformation of the body under normal static load conditions wherein said configuration inhibits formation of zones of high stress concentration at the cavity wall.

The cross-sectional configuration assumed by the cavity upon the resilient deformation of the body may be a closed curve.

The configuration of the cavity pref rably inhibits deformation of the cavity wall to an extent which would allow wall sections thereof to come into contact one

with anoth r. In this way, deformation of the cavity wall to th xt nt wh re a tight radius of curvature is formed ther in is also inhibited.

The cavity may be arranged to assume said cross-sectional configuration upon resilient deformation of the body through appropriate selection of the initial cross-sectional shape of the cavity in the undeformed condition of body.

There may be various cross-sectional shapes suitable for the cavity in the undeformed condition of the body. A feature common to the majority, if not all, of the suitable cavity cross-sectional shapes is that they are rounded without being circular. The rounded shape may, for instance, be triangular with rounded corners, or polygonal with rounded corners. Another suitable rounded shape may comprise a pair of spaced apart arcs with the concave sides thereof in facing relationship and intermediate lines extending between the arms. The two arcs may have radii of curvature which are equal or unequal. Where the arcs are unequal, the larger arc may be disposed towards either the outer side or the inner side of the body. The intermediate lines extending between the arcs may be curved, straight or of some other configuration. Where the intermediate lines are curved, the shape of the cavity in cross section may be a closed curve such as an ellipse or ovoid. Preferably, the cavity is longitudinal and of a substantially constant orientation throughout its length within the body.

In the undeformed condition of the body, the cavity may be elongate in cross-section. In such a case, the elongate cavity may be so disposed that the major axis of the cross-sectional shape of the cavity is substantially normal to the direction of cyclical movement of the ground-engaging structure. For instance, where the ground-engaging structure is a tyre, the major axis of the cavity cross-sectional shape would be aligned with a radial axis of the tyre.

The feature wh reby the cavity is elongate in cross-section and oriented such that the major axis of the cross-sectional shape is substantially normal to th direction of cyclical movement of th ground-engaging structure is

advantageous for such a structure which is intended for bi-directional use. This is because the major ext nt of th cavity in cr ss-s ction is aligned with vertical loadings imposed on the deforming body of the ground-engaging structure when subjected to static loads. In this way, the cavity wall is better able to deform on resilient deformation of the body of the ground-engaging structure without distorting to provide a zone having a tight radius of curvature within the cavity or having surfaces of the cavity wall coming into contact with each other.

The circumstances where the ground-engaging structure is of uni-directional use, it may be that the major axis of the cross-section of the cavity is inclined to the normal direction of cyclical movement in order to resist torsional loadings on the structure.

Regardless of whether the cavity is elongate in cross-section, it preferably has two opposed end portions in cross-section which are aligned with a direction substantially normal to the direction of cyclical movement of the ground-engaging structure. In other words, the two end portions of the cross-section are in opposing relationship and spaced along a line which extends therebetween normal to the direction of cyclical movement of the ground- ngaging structure. One of the end portions may be enlarged with respect to the other.

The body may be provided with a plurality of the cavities.

In addition to enhancing resilience of the body, the cavities provide ventilation for assisting in heat dissipation.

The cavities conveniently each extend cross-wise through the body with both nds of the cavity opening onto the exterior of the body. Other arrangements are, however, possible. The cavities may be open at one end and closed at the other end. The cavities may also be open at both ends and closed internally.

Th re may also be combinations of such arrangem nts, with some caviti s having one arrangement and other cavities having diff rent arrangements.

Where it is desirable to provide a non-pneumatic tyre which resembles a pneumatic tyre, the cavities may be arranged to open only onto a common side of the resiliently deformable body. With this arrangement, all of the cavities would be visible when the tyre is viewed from the common side but none of the cavities would be visible when the tyre is viewed from the opposite side. The opposite side may then provide the appearance of a pneumatic tyre or at least provide an uninterrupted side wall area onto which a manufacturer can emboss or otherwise incorporate trade mark and/or other marketing indicia onto the tyre.

The cavities may be in a circumferentially spaced apart relationship. The spacing between neighbouring cavities may be substantially equal. ~~The circumferential spacing between the cavities provides load-supporting webs between the cavities.~~

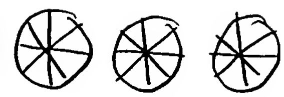
The cavities may comprise a first set of cavities within the resiliently deformable body.

There may be a second set of cavities in the resiliently deformable body. The cavities in the second set may be of any appropriate cross-sectional shape and not necessarily a shape which has the features of the cavities of the first set. For example, the cavities in the second set may have a cross-sectional shape which is simply circular in the undeformed condition of the body. It may, however, be desirable for the cavities of the second set to have the features of the cavities of the first set, particularly if they would otherwise be susceptible to formation of zones of high stress concentration.

The caviti s in the second set may be in a circumferentially spaced apart relationship.

The cavities in the first and second sets may b in a staggered r lationship with respect to ach other or there may be alignment between the cavities. In the latter case, each cavity in the second set may be aligned with a respective cavity in the first set along a line normal to the direction of cyclical movement of the ground-engaging structure. Thus, in a tyre the respective aligned cavities would be aligned along a radial axis of the tyre.

The resiliently deformable body may incorporate reinforcement for the purpose of enhancing the strength and durability of the ground-engaging structure.



In one arrangement, the resiliently deformable body may have an outer surface for contact with the ground, in which case it may be provided with a tread formation. In another arrangement, the outer surface of the resiliently deformable body may be adapted to support another structure which provides the tread or otherwise facilitates engagement with the ground.

The resiliently deformable body may have an inner surface for engagement with a cyclically movable support. In the case of a ground-engaging structure in the form of a tyre, the cyclically movable support may comprise a wheel rim. In the case of a ground-engaging structure for an endless track, the cyclically movable support may comprise an endless band passing around track rollers.

The ground-engaging structure may be of a one-piece construction or it may be formed of a plurality of ground-engaging segments which can be assembled together to provide a ground-engaging structure of composite construction. A ground-engaging structure of one-piece construction is advantageous in that it generates less heat during operation than a structure of composite construction. This is because the one-piece construction does not have the interfaces between the segments which exist in the composite construction, which interfaces are in rubbing contact during cyclical movement of the ground-engaging structure.

Th invention also provides a ground-engaging segment which along with other such segments can be assembled to form a ground-engaging structure as hereinbefore defined.

Each segment may comprise a resiliently deformable body having provided therein a cavity bounded by a cavity wall, the cavity being arranged to assume a cross-sectional configuration upon resilient deformation of the body under normal static load conditions, wherein said configuration inhibits formation of zones of high stress concentration at the cavity wall.

The body of the segment may have a plurality the said cavities provided therein.

Performance characteristics of the resiliently deformable body of the ground-engaging structure or the ground-engaging segment may be enhanced by making it of a laminate construction. More particularly, the body may have an inner portion for positioning on a cyclically movable support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed as layers of materials having different hardness characteristics.

The outer portion is preferably elastomeric material having wear resistance characteristics suitable to provide a tread structure such as rubber having a hardness of about 63 to 75 Shore A and preferably within the range 65 to 70 Shore A.

The intermediate layer is preferably of elastomeric material suitable to provide load support and cushioning, such as rubber having a hardness of about 55 to 75 Shore A.

In one arrangem nt, the inner portion may be formed of elastomeric material of a hardness suitable for gripping engagement with the cyclically movable support

such as rubber having a hardness of about 75 to 96 Shore A and pref rably within the rang 80 to 90 Shore A. With such an arrang m nt, the inner portion may include reinforcing means such as circumferential reinforcing rings. In another arrangement, the inner portion may comprise a substantially rigid band such as a steel ring.

The inner portion may be of integral construction or it may be of a split construction so that it can expand and contract to facilitate installation of the tyre onto the support. In the case of a split construction, the inner portion may comprise a plurality of segments positioned in circumferential relationship such that the segments can move into a circumferentially spaced apart relationship upon expansion of the inner portion.

While the cavities are preferably located entirely within the intermediate layer, they may penetrate the outer layer, the inner layer, or both of the outer and inner layers.

The present invention also provides a cyclically movable ground-engaging structure comprising an annular body having an inner portion for positioning on a support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed as layers of materials having different hardness characteristics.

The present invention still further provides a segment for a cyclically movable ground engaging structure, the segment comprising a body having an inner portion for positioning on a support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed of materials having different hardness charact ristics.

The inv ntion still furth r provid s a cyclically movabl gr und-engaging structure comprising a resiliently deformable body having provided th rein a plurality of cavities in circumferentially spaced apart relationship, the cavities each having a cross-section which is elongate. The elongate cross-section of each of said cavities may have a major axis and wherein the cavity is oriented such that the major axis of the cross-section thereof is substantially normal to the direction of cyclical movement. The cross-section of each of said cavities comprises two opposed end portions in opposed relationship along said major axis, wherein each of said end portions comprises an arc. The end portions may be entirely arcuate. The arcs may have equal or unequal radii of curvature.

The present invention still further provides a cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arranged in circumferentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from the inner surface, each of the cavities in the second set being aligned in a direction normal to the direction of cyclical movement with a respective one of the cavities in the first set.

The present invention still further provides a cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arranged in circumferentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from the inner surface, each of the cavities in the second set being aligned in a direction normal to the direction of cyclical movement with a respective one of the cavities in the first set, the cavities in the first set being of a rounded configuration in cross-section and the cavities in the second set being circular in cross-section.

Th present inv ntion still further provides a cyclically movabl ground-engaging structure comprising a resiliently deformabl body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arranged in circumferentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from the inner surface, at least some of the cavities in at least one of the first and second sets being of non-circular cross-section.

Brief Description of the Drawings

The invention will be better understood by reference to the following description of various specific embodiments thereof.

The description will be made with reference to the accompanying drawings in which:

Fig. 1 is a schematic view of a non-pneumatic tyre of the type known in the prior art, with the tyre being illustrated in an unloaded condition;
Fig. 2 is a view similar to Fig. 1 with the exception that the tyre is illustrated in a deformed condition under a static load;
Fig. 3 is a perspective view of a tyre according to a first embodiment of the invention;
Fig. 4 is a fragmentary perspective view of the tyre of the first embodiment;
Fig. 5 is a fragmentary side elevational view of the tyre of the first embodiment;
Fig. 6 is a fragmentary schematic elevational view illustrating the tyre of the first embodiment in contact with the ground and deflecting under a static load condition;
Fig. 7 is a view similar to Fig. 6 except that th tyre is shown defl cting under a high torque loading condition;

Fig. 8 is a sid view of a wheel fitt d with a tyre according to a second embodim nt, the tyre being of composite construction comprising an assembly of tyre segments;

Fig. 9 is a perspective view of a tyre segment for the tyre of Fig 8;

Fig. 10 is a perspective view of a tyre according to a third embodiment;

Fig 11. is a side view of the tyre of Fig 10 shown fitted on a wheel rim;

Fig. 12 is an end view of the tyre of the third embodiment showing the tread structure;

Fig. 13 is a cross-sectional view along the line 13-13 of Fig. 11;

Fig. 14 to 20 inclusive are schematic views of the tyre according to the third embodiment deflecting under various static loads;

Fig. 21 is a cross-sectional view of a tyre according to a fourth embodiment fitted onto a wheel rim;

Fig. 22 is a cross-sectional view of a tyre according to a fifth embodiment fitted onto a wheel rim;

Fig. 23 is a side view of a tyre according to a sixth embodiment;

Fig. 24 is a schematic side view of the tyre of a seventh embodiment deforming under load;

Fig. 25 is a fragmentary side view of the tyre of the seventh embodiment showing the deformation under load;

Fig. 26 is a side view of a tyre according to an eighth embodiment;

Fig. 27 is a fragmentary side view of the tyre according to the eighth embodiment;

Fig. 28 is a side view of a tyre according to a ninth embodiment;

Fig. 29 is a fragmentary view on an enlarged scale showing the configuration of apertures in the embodiment of Fig. 28;

Fig. 30 is a fragmentary view showing the configuration of apertures in a tyre according to a tenth embodiment;

Fig. 31 is a schematic side view of a tyre according to an eleventh embodiment;

Fig. 32 is a cross-sectional view of the tyre according to th embodiment; of Fig. 31;

Fig. 33 is a cross-sectional view of a tyr according to a tw lfth mbodim nt;

Fig. 34 is a schematic view of a tyre segment for assembly along with other such tyre segments to provide a tyre according to a still further embodiment;

Fig. 35 to 39 inclusive illustrate various other shapes for cavities in ground-engaging structures according to the invention when in an undeformed condition;

Fig. 40 is a schematic side view of an endless track for a tracked vehicle incorporating a ground-engaging structure according to a still further embodiment.

Fig. 41 is a schematic perspective view of an endless track providing a ground-engaging structure according to a still further embodiment; and

Fig 42 is a fragmentary view of the ground-engaging structure of Fig. 41.

Description of Preferred Embodiments

15+

The embodiment shown in Figs. 3 to 7 of the accompanying drawings is directed to a cyclically movable ground-engaging structure in the form of a non-pneumatic tyre 10 which is intended primarily for operation in rough terrain and would typically be used on vehicles with a four-wheel-drive capability. The tyre 10 is shown in engagement with a ground surface 11 in Figs. 6 and 7 of the drawings.

The tyre 10 comprises an annular body 12 formed of elastomeric material such as rubber. The annular body 12 may incorporate suitable reinforcement, although no such reinforcement is illustrated in the drawings.

The annular body 12 comprises a radially inner end 13 including inner face 15 for engagement with a cyclically movable support such as a wheel rim (not shown) and a radially outer end 17 including outer face 19 for contact with the ground. A tr ad formation 21 is provided in the out r face 19 for gripping

engag m nt with the ground surface. A pair of opposed sid walls 23 xt nd b tween the inner portion 13 and outer portion 17.

A plurality of circumferentially spaced longitudinal cavities 25 are provided within the annular body 12. Each cavity is bounded by a cavity wall 32. The cavities are each of a constant orientation within the annular body 12 throughout the length of the cavity. The cavities 25 provide core holes which extend between, and open onto, the opposed side walls 23. In this embodiment, the cavities 25 are positioned in close proximity to the radially inner face 15, as shown in the drawings.

The circumferential spacing of the cavities 25 provides load-supporting webs 27 therebetween.

Each cavity 25 has a cross-sectional shape which is an elongate closed curve 26 of ovoidal form. The closed curve 26 defining the cross-sectional shape of each cavity 25 can be considered as two arcs 26a, 26b respectively defining a radially outer end portion 25a and a radially inner end portion 25b of the cross-sectional shape of the cavity, as shown in Fig. 5. The arcs 26a, 26b are connected by intermediate lines 26c, 26d to complete the closed curve. The intermediate lines 26c, 26d are arcuate.

The elongate closed curve 26 of each cavity 25 has a major axis 28 centred along the length thereof, as shown in Fig. 5. The closed curve 26 also has a further axis 29 which is transverse to the major axis 28 and which corresponds to the maximum transverse dimension (width) of the curve.

The cavities 25 are each oriented such that the larger end thereof is disposed towards the radially outer end of the tyre. The ovoidal shape of each cavity 25 and th orientation of th cavity provides an arrangement in which the centroid of the cavity is adjacent to the end th reof which is towards th radially outer

nd of the tyre. With this orientation, the major axis 28 of the ovoidal shap xtends in a radial direction of th tyre.

The ratio of the dimension of each cavity 25 along the major axis 28 to the dimension along the further axis 29 is up to 2:1. More particularly, the ratio is in the range 1.1:1 to 1.7:1, and is preferably 1.2:1.

The ratio of up to 2:1 is advantageous as it provides a tyre which has sufficient resilience for a comfortable ride while providing adequate load support for normal working conditions.

The ovoidal shape of the cavities 25 is particularly useful. It provides each cavity with a raised ceiling portion 30 which provides good support for the region 31 of the annular body 12 disposed outwardly of the cavity such that the load supporting characteristics of that region is somewhat similar to the load supporting characteristics of the neighbouring regions 33 disposed outwardly of the webs 27 between the cavities. This provides a smooth, cushioned ride as the tyre rolls over the ground. If the load carrying characteristics between the regions 31 and 33 were substantially different, the tyre may provide an uneven ride when travelling over smooth surfaces.

The ovoidal configuration of the cavities 25 also avoids, or at least inhibits, formation zones having tight radii of curvature which generate stress raisers within the annular body 12 when it is under normal working loads, being either static loads as illustrated in Fig. 6 or torque loads as illustrated in Fig. 7. Indeed, under static loading as illustrated in Fig. 6, the radius of curvature of each of the arcs 26a, 26b increases with the result that the cross-section configuration of the cavity approaches a circular form. This discourages formation of stress raisers of the type of concern. The presence of stress raisers can g nerate excessive heat which contributes to det rioration of the tyre and a reduction of its service life.

Referring particularly to Fig. 7, the tyre 10 wh n subjected to high tractiv load distorts to an ext nt that th cavities 25 develop an elongated, skewed shape but still maintain a substantially rounded condition. Consequently, zones having tight radii of curvature of the type illustrated in the prior art tyre shown in Fig. 2 are not developed.

[redacted] This serves several purposes, one being that it [redacted]

[redacted]

While in this embodiment, the radially outer arc 26a has a larger radius of curvature than the radially inner arc 26b, a reverse arrangement may well apply in other situations.

2nd

The tyre according to the first embodiment is of one-piece construction. The second embodiment which is illustrated in Figs. 8 and 9 of the drawings, is directed to a tyre 40 which is somewhat similar to the tyre 10 of the first embodiment with the exception that, rather than being of one-piece construction, it is of composite construction which can be assembled from a plurality of tyre segments 41. Each tyre segment 41 comprises a body 48 of resiliently deformable tubular construction to provide the necessary cavity 45 therein. The tyre segments 41 can be positioned in circumferentially end-to-end relationship around a cyclically movable support in the form of a wheel rim 42 to provide th composite tyre 40. Each tyre segment 41 is adapted t be individually and removably fixed on a support face 43 of the wh el rim 42 by any suitable means

such as by bonding or by a fast ning system 46 which includes a clamping plate 47 received in th cavity 45 and secured to th wheel rim 42 by s curing bolts 49. Fixing the tyre segments 41 to the wheel rim 42 in such fashion allows them to be replaced on an individual basis in the event of damage.

The tyre segments 41 are a V-shape as shown in Fig 9 so that they can be mounted in interlocking engagement one with another on the wheel rim 42.

3rd

Referring now to Figs. 10 to 20 of the accompanying drawings, a tyre 51 according to the third embodiment comprises an annular body 53 formed of resiliently deformable material such as rubber. Reinforcement is incorporated into the rubber, as will be explained later.

The annular body 53 has an inner portion 55 configured to fit onto a wheel rim 56 and an outer portion 57 provided with a tread 58 for contact with the ground. The body 53 also has opposed sides 59. The wheel rim 56 in this embodiment is a conventional split-rim.

A plurality of cavities 60 are provided in the annular body 53 to enhance its resilience for the purposes of providing a cushioned ride. The cavities extend cross-wise through the annular body 53 and open onto the opposed sides 59 thereof. The cavities 60 are arranged in two sets, being cavities 63 in a first set 61 and cavities 65 in a second set 62. The cavities 65 in the second set 62 are positioned radially inwardly of the cavities 63 in the first set 61, as shown in the drawings.

The cavities in each set 61, 62 are positioned in circumferentially spaced apart relationship. There is a one-to-one correspondence of cavities 63 in the first set 61 with respect to cavities 65 of the second set 62 whereby each of the cavities in the first set is aligned with one of the cavities in the second set in the radial direction of the tyre. In this embodim nt, the radial alignment is such that ach

of th cavities 63 in the first s t 61 is centred on a radial lin which passes through the centre of th respectiv cavities 65 in the second set 62.

The cavities 63 in the first set 61 are of larger cross-sectional area than the cavities 65 in the second set 62. An advantage of the cavities 63 being of a larger cross-sectional area than the cavities 65, is that it avoids use of excessive elastomeric material in the outer region of the tyre where it is structural unnecessary. This has two benefits; first, it provides the outer peripheral region of the tyre with greater resilience than the inner region, and secondly, it reduces the amount of elastomeric material within the tyre so reducing the amount of heat likely to be generated during operation of the tyre. The greater resilience of the outer peripheral region of the tyre provides for a relatively soft ride in load conditions. As loading increases, the impact of reduced resilience of the inner peripheral region progressively increases so providing a progressively harder ride.

In this embodiment, the cavities 63, 65 are of generally triangular configuration with rounded corners. The rounded nature of the cavities 63 and 65 avoids, or at least inhibits, formation of zones of tight radii of curvature at the walls of the cavities as the annular body deforms under normal working loads. The tyre is shown in Figs. 14 to 20 in conditions in which it is deflecting under the influence various static loadings.

The cavities 63 in the first set 61 are oriented in alternate arrangements such that some cavities have a base 69 thereof outermost and alternate cavities have an apex 73 thereof outermost. With this arrangement, load-bearing webs 75 defined between neighbouring cavities 63 in the first set 61 have a substantially constant wall thickness. The arrangement also provides the webs 75 with an orientation with respect to the radial direction of the tyre. More particularly, neighb uring webs 75 are inclined in opposing directions, as shown in the drawings. The f ature whereby th load-bearing webs 75 are inclined with respect to the radial direction of the tyre, and in alternate opposing directions,

provid s th tyre with the ability to withstand high torqu loadings. Th inclined load-bearing webs 75 act as braces to resist circumferentially twisting betw en the outer and inner regions of the tyre when the tyre is subjected to high torque loadings.

The spacing between cavities 65 in the second set 62 also provides load-bearing webs 77.

Because the cavities 63 in the first set 61 are each aligned with a respective one of the cavities 65 in the second set 62, a circumferential web 79 is defined between aligned cavities 63 and 65.

The arrangement of the various webs 75, 77 and 79 provides a system for distributing vertical and tractive loads imposed on the tyre within the tyre so that the loadings are not localised in the region of ground contact.

The inner portion 13 of the tyre incorporates reinforcing strands 72.

While the cavities 63 in the first set 61 have been shown centred on a common pitch circle, it should be understood that they may be arranged in some other arrangement such as a staggered arrangement. Similarly, while the cavities 65 in the second set 62 have also been shown centred on a common pitch circle it should be understood that they may be arranged in any other suitable fashion.

In this embodiment, the cavities 60 extended completely through the annular body 53. There may be circumstances where it is advantageous for the cavities not to extent completely through the body. Referring now to Fig. 21, there is illustrated a tyre according to a fourth embodiment which is similar to the tyre of the third embodiment except that the cavities 63, 65 open onto one side of the tyre only. More particularly, the cavities 63, 65 xtend laterally into the annular body 53 from a common side 59 th reof and terminate inwardly of the opposed side of the body. In this way, the cavities 63, 65 are not visible from the

opposed side of th body 53, and thus when viewed from that side the tyre does not hav the appearance of a non-pneumatic tyre incorporating cavities to provide resilience. The opposed side of the tyre provides an uninterrupted surface onto which a manufacturer may incorporate trade mark material or other indicia such as information relating to the size and load-carrying characteristics of the tyre.

The fifth embodiment, which is shown in Fig. 22, is also similar to the third embodiment except that cavities 63, 65 extending laterally into the body from both sides are positioned in pairs, with the two cavities of each pair being on opposite sides of the tyre and extending laterally inwardly in opposed relationship. The two cavities of each pair terminate inwardly of each other to define a partition 66 therebetween.

Referring now to the sixth embodiment, which is shown in Figs. 23 of the drawings, there is shown a tyre 51 which is somewhat similar to that of the third embodiment with the exception that the cavities 65 in the second set 62 are of generally circular configuration.

The tyres according to the fourth, fifth and sixth embodiments are arranged to operate at relatively high load and low speed conditions. These conditions normally apply in industrial and mining environments. One particular application for the tyres is on [redacted]

There are other environments in which it is desirable to have a tyre which operates at higher speed and lower load conditions. One such arrangement would be non-pneumatic tyres fitted to [redacted] The embodiment shown in Figs. 24 and 25 is directed to a non-pneumatic tyre 80 which can operate at higher speeds than the tyres according to the previous embodiments. The tyre according to this mbodiment is somewhat similar to the tyres of the previous embodim nts in that caviti s in the resili ntly deformable annular body 82 are arranged in two s ts, being cavities 83 in a first s t 81 and cavities 85 in a

second set 82. The cavities 83, 85 in this embodiment are, how v r, of a cross-section which is gen rally rectangular configuration with round d corners.

In the various embodiments, the apertures have been described as being arranged in two sets; namely, a first set which is outermost and a second set which is innermost. There may, however, be situations in which it is advantageous to provide cavities in more than two sets. In such a case, the cavities may increase in cross-sectional area in the radially outward direction.

In the embodiment which is shown in Figs. 23, the cavities 63, 65 are of triangular configuration, somewhat resembling an equilateral triangle with rounded corners. The embodiment shown in Figs. 26 and 27 is somewhat similar to the embodiment of Fig. 23 with the exception that the cavities 63 in the first set 61 are of a configuration comprising two spaced apart arcs 63a, 63b with the concave sides thereof in facing relationship, and curved lines 63c, 63d extending between the arcs to complete the closed curve. The closed curve somewhat resembles an isosceles triangle with rounded corners. The major axis of each isosceles triangle is aligned with a radial axis of the tyre. Additionally, the radius of curvature of rounding of each of the corners of the triangular shape in this embodiment is larger than that in the third embodiment, as can be seen from the drawings. The more generous rounding at the corners of this embodiment assists in further reducing the tendency of the corners of fold about themselves under high load conditions. Any such folding may create zones of tight radii at the corners which could lead to excessive heat generation resulting in degradation of the rubber and premature failure of the tyre.

In this embodiment, alternate cavities 63 of the first set 61 are radially offset with respect to each other to a slight extent.

The embodim nt shown in Figs. 28 and 29 of the accompanying drawings is also s mewhat similar to the mbodim nt shown in Fig. 23. In this embodim nt, at least some of the cavities 63 in the first set 61 are of generally circular

cross-section configuration. More particularly, th cavities 63 are so arrang d that alternat apertures are of a g nerally circular configuration. The remaining apertures are of generally triangular configuration with rounded corners and the apex of each such cavity positioned outermost.

The embodiment shown in Fig. 30 is somewhat similar to the previous embodiment except that the cavities 63 in the first set 61 are no longer staggered in relation to each other; that is, the spacing between the tread and each cavities 63 is substantially equal.

It is believed that the tyres according to the two immediately preceding embodiments may have improved rolling characteristics (so as to provide a smoother ride) in comparison to tyres according to the earlier embodiments.

In the previous embodiments, the resiliently deformable body of the tyre has been of unitary construction. It [redacted] The embodiment shown in Figs. 31, 32, and 33 provides such a tyre.

laminate construction

Referring to Figs. 31 and 32, the tyre comprises an annular body 90 of laminate construction comprising three layers of rubber including an inner layer 91, an intermediate layer 92 and an outer layer 93. The three layers are distinct and are bonded to each other at respective interfaces 95. The characteristics of the layers are selected according to the respective functions that the layers are to perform, as will be explained later.

[redacted] a [redacted]). [redacted]

The intermediate layer 92 is provided for load supporting and cushioning purposes.

While the rubber employed for the intermediate layer 92 is resilient for the purposes of cushioning, the cushioning characteristics are enhanced by the presence of cavities 99 formed therein. The cavities 99 are of rounded cross-sectional shape and extend across the tyre to open onto opposed side faces 100 of the annular body 91.

The cavities 99 are arranged in two sets, being a first set 101 comprising a plurality of circumferentially spaced cavities 103, and a second set 102 comprising a plurality of circumferentially spaced cavities 105.

The cavities 103 in the first set 101 are of larger cross-sectional area than the cavities 105 in the second set 102. The difference in the cross-sectional areas of the cavities 103 and 105 reduces the amount of elastomeric material used in the outer circumferential region of the intermediate layer 92 of the tyre. This assists in providing the outer region of the intermediate layer 92 with greater resilience than the inner region thereof and also reduces the amount of elastomeric material within the tyre so reducing the amount of heat likely to be generated during operation of the tyre. The greater resilience of the outer circumferential region of the intermediate layer 92 provides for a relatively soft ride in load conditions. As loading increases, the impact of the reduced resilience of the inner circumferential region arising from the smaller cavities 105 progressively increases so providing a progressively harder ride.

The cavities 105 in the second set 102 are of generally circular cross-sectional configuration, and the cavities 103 in the first set 101 are of generally triangular configuration with rounded corners. The cavities 103 in the first set 101 are oriented in alternat arrangem nts, as shown in Fig. 31.

The inner portion provided by the inner layer 91 requires greater stiffness than the other layers to facilitate gripping of the tyre onto the wheel rim. Such stiffness may be enhanced by the presence of reinforcement means 107 such as reinforcement rings 109.

The outer layer 93 which provides the tread structure 97 must be durable so as to provide good wear resistant characteristics.

In this embodiment, the hardness of the various layers 91, 92 and 93 decreases in the radially outward direction of the tyre. The inner layer 91 is of hard rubber, being rubber having a hardness in the range of about 85 to 90 Shore A. The intermediate layer 92 is somewhat softer for cushioning and load support, and has a hardness of about 70 to 75 Shore A. The outer layer 93, which provides the tread structure 17, is formed of rubber selected for wear resistance so as to provide good service life and has a hardness of 63 to 65 Shore A.

The next embodiment, which is shown in Fig. 33 of the drawings, is somewhat similar to the immediately preceding embodiment inasmuch as it comprises a body of laminate construction including an inner layer 91, an intermediate layer 92, and an outer layer 93. However, in this embodiment, the inner layer 91, which provides the inner portion of the tyre for mounting onto a wheel rim, comprises a rigid band 111 in the form of a steel ring. The steel ring is arranged to be fitted onto the wheel rim by way of an interference fit.

The intermediate layer 92 is bonded onto the steel ring 111 and includes a plurality of cavities 113 in circumferentially spaced relationship and of a cross-section which is generally triangular with rounded corners.

The embodiment shown in Figs. 8 and 9 is directed to a composite tyre assembled from a plurality of tyre segments. It should be understood that any of the other embodiments directed to a one-piece tyre could also be of composite construction. In this regard, the embodiment shown in Fig. 34 of the drawings

illustrates a tyre segment 120 which along with similar such segments can be assembled on a wheel rim to form a composite tyre. The assembled composite tyre would have a first set of cavities in circumferentially spaced relationship and a second set of cavities in circumferentially spaced relationship, the first and second sets being radially offset with respect to each other, as is illustrated in some of the earlier embodiments.

The tyre segment 120 comprises a body 121 of resilient deformable material and a plurality of cavities provided therein. The cavities extend through the body and open onto the opposed ends 125 thereof. The cavities comprise a pair of first cavities 127 and a second cavity 129. The cavities 127, 129 are of rounded shape in cross-section as shown in the drawing. The pair of first cavities 127 form, along with corresponding cavities in similar such tyre segments, the first set of cavities in the composite tyre. Similarly, the second cavity 129, along with corresponding cavities in similar such tyre segments, form the second set of cavities in the composite tyre.

From the various embodiments which have been described and illustrated, it is evident that the cavities formed in the resiliently deformable body, whether of one-piece construction or segmented construction, can be of various cross-sectional shapes. Various other cross-sectional shapes may also be suitable including the shapes illustrated schematically in Figs. 35 to 39 of the accompanying drawings. Each of the illustrated shapes 130 is elongate so as to have a major axis 132 and a further axis 134 transverse to the major axis 132 at a location corresponding to the maximum width. In the shape illustrated in Fig. 39, there are two such further axes. The shapes each have two end portions 131 in opposed relationship along the major axis. Typically, the cavities would be so arranged that each has the major axis of its cross-sectional shape normal to the direction of cyclical movement of the ground-engaging structure.

Each shape 130 is a closed curv comprising a pair of arcs 133 in opposing relationship and two int rmediat lines 135 extending between the arcs 133 to

compl te th closed curve. From the various figures, it can be seen that the int rmediat lines 135 can be straight or curved.

The various shapes 130 have a ratio of the dimension along the major axis 132 to the dimension along the minor axis up to 2:1. In the shape illustrated in Fig. 35, the ratio is preferably within the range 1.4:1 to 1.6:1.

The various embodiments which have been described have been directed to ground-engaging structures in the form of tyres for wheels. A ground-engaging structure according to the invention can also be applied to an endless track for a tracked vehicle. One such ground-engaging structure will now be described in relation to Fig. 40 of the accompanying drawings.

The ground-engaging structure 140 illustrated in Fig. 40 of the drawings comprises endless band 141 passing around track end rollers 143. The endless band 141 is supported between the end rollers 143 by an upper support roller 145 and a plurality of spaced apart lower support rollers 147.

The endless band 141 is of one-piece construction and comprises a body 149 formed of resiliently deformable material such as rubber. The body may incorporate reinforcement means (not shown). The body 149 is configured to define a plurality of spaced apart ground-engaging pads 151 each of which includes a rounded cavity 153 extending therethrough. As with the embodiment described in relation to a tyre, the shape of the cavity 153 is such that it avoids, or at least inhibits, formation of zones of high stress concentration in the resiliently deformable pads 151 when they deform under normal working loads.

While the ground-engaging structure according to the embodiment shown in Fig. 40 is of one-piece construction, it is also possible for it to be of segmented construction. One such construction is illustrated in the embodiment shown in Figs. 41 and 42 of the accompanying drawings. In this embodiment, the ground-engaging structure 160 is supported on a flexible endless band 161 having an

out r face 162. Th band 161 is adapted to be mounted for cyclical mov m nt about track nd roll rs (not shown). The ground-engaging structure 160 comprises a plurality of track segments 163 having an inner face 164 supported on the outer face 162 of the endless band 161. Each track segment 163 comprises a resiliently deformable body 165 having one or more cavities provided therein. In this embodiment, each resiliently deformable body 165 has three cavities, being a pair of first cavities 167 and a second cavity 169. The pair of first cavities 167 co-operate with similar such cavities in other track segments to provide the ground-engaging structure with a first set 171 of cavities. Similarly, the second cavity 169 co-operates with corresponding cavities of other track segments to provide the ground-engaging structure with a second set of cavities 172 spaced inwardly of the first set.

The various track segments are individually and preferably releasably secured to the endless band 161 by any suitable means such as by bonding or a detachable fixing system.

From the foregoing, it is evident that the ground-engaging structures according to the various embodiments, whether they relate to tyres or endless tracks and indeed whether they are of one-piece or composite construction, provide a simple yet highly effective arrangement for avoiding, or at least reducing, undesirably high stress concentrations in the ground-engaging structures when deforming under normal working loads. This is achieved by selection of the cross-section shape of the cavities within the resiliently deformable body of the structure so that upon deformation under normal working loads the cavities deform to closed curves without creation of zones of tight radii which would cause undesirable stress raisers or having wall sections coming into contact one with another.

It should be appreciated that th scope of th invention is not limited to th scope of the various mbodim nts d scribed.

Claims

1. A cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a cavity bounded by a cavity wall, the cavity being arranged to assume a cross-sectional configuration upon resilient deformation of the body under normal static load conditions wherein said configuration inhibits formation of zones of high stress concentration at the cavity wall.

2. A cyclically movable ground-engaging structure according to claim 1 wherein the cross-sectional configuration assumed by the cavity upon the resilient deformation of the body comprises a closed curve.

3. A cyclically movable ground-engaging structure according to claim 1 or 2 wherein the cavity is arranged to assume said cross-sectional configuration upon resilient deformation of the body through formation of the cavity in a suitable cross-sectional shape in the undeformed condition of the body.

4. A cyclically movable ground-engaging structure according to claim 3 wherein the cavity comprises a longitudinal cavity having a cross-sectional shape which is rounded without being circular.

5. A cyclically movable ground-engaging structure according to claim 4 wherein the cross-section of the cavity is generally triangular with rounded corners.

6. A cyclically movable ground-engaging structure according to claim 5 wherein the cross-section of the cavity is generally polygonal with rounded corners.

7. A cyclically movable ground-engaging structure according to claim 5 or 6 wherein at least one side of the triangle or polygon is arcuate.

8. A cyclically movable ground-engaging structure according to claim 4 wherein the cross-section of the cavity comprises a closed curve.

9. A cyclically movable ground-engaging structure according to claim 4 wherein the cross-section of the cavity comprises a pair of spaced apart arcs with the concave sides thereof in facing relationship and intermediate lines extending between the arcs.

10. A cyclically movable ground-engaging structure according to claim 9 wherein said arcs have radii of curvature which are unequal.

11. A cyclically movable ground-engaging structure according to claim 9 or 10 wherein said lines extending between the arcs are curved.

12. A cyclically movable ground-engaging structure according to claim 11 wherein the cross-section of the cavity is an ellipse or ovoid.

13. A cyclically movable ground-engaging structure according to any one of claims 4 to 12 wherein the cavity is elongate in cross-section in the undeformed condition of the body.

14. A cyclically movable ground-engaging structure according to claim 13 wherein the elongate cavity is so disposed that the major axis of the cross-sectional shape of the cavity is substantially normal to the direction of cyclical movement of the ground-engaging structure.

15. A cyclically movable ground-engaging structure according to any one of claims 4 to 14 wherein the cavity has two opposed end portions in cross-section which are aligned substantially with a direction normal to the direction of cyclical movement of the ground-engaging structure.

16. A cyclically movable ground-engaging structure according to claim 15 wherein one of th end portions is enlarged with respect to the other.

17. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the cavity opens onto the exterior of the body and extends into the body.

18. A cyclically movable ground-engaging structure according to claim 17 wherein the cavity extends cross-wise through the body with both ends of the cavity opening onto the exterior of the body.

19. A cyclically movable ground-engaging structure according to claim 17 wherein the cavity is open at one end and closed at the other end.

20. A cyclically movable ground-engaging structure according to claim 17 wherein the cavity is open at both ends and closed internally.

21. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the cavity comprises a core hole.

22. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the body is provided with a plurality of said cavities.

23. A cyclically movable ground-engaging structure according to claim 22 wherein the cavities are in a circumferentially spaced apart relationship, the spacing between the cavities providing load-supporting webs between the cavities.

24. A cyclically movabl ground-engaging structure according to claim 22 or 23 wherein th cavities comprise a first set of caviti s within th resili ntly deformable body.

25. A cyclically movabl ground-engaging structure according to claim 24 further comprising a second set of cavities in the resiliently deformable body.

26. A cyclically movable ground-engaging structure according to claim 25 wherein the cavities in the second set are in a circumferentially spaced apart relationship.

27. A cyclically movable ground-engaging structure according to claim 25 or 26 wherein the cavities in the first and second sets are in a staggered relationship with respect to each other.

28. A cyclically movable ground-engaging structure according to claim 25 or 26 wherein each cavity in the second set is aligned with a respective cavity in the first set along a line normal to the direction of cyclical movement of the ground-engaging structure.

29. A cyclically movable ground-engaging structure according to any one of claims 25 to 28 wherein the cavities of the second set are disposed inwardly of the cavities in the first set and are of a smaller cross-sectional area than the cavities of the first set.

30. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the resiliently deformable body incorporates reinforcement for the purpose of enhancing the strength and durability thereof.

31. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the resiliently deformable body has an outer surface for contact with the ground.

32. A cyclically movable ground-engaging structure according to any one of claims 1 to 30 wherein the resiliently deformable body has an out r surface

adapt d to support another structure which provides a tread or otherwis facilitates engagement with th ground.

33. A cyclically movable ground-engaging structure according to any one of the preceding claims resiliently deformable body has an inner surface for engagement with a cyclically movable support.

34. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein it is of a one-piece construction.

35. A cyclically movable ground-engaging structure according to any one of claims 1 to 33 wherein it comprises a plurality of ground-engaging segments which can be assembled to provide the ground-engaging structure of composite construction.

36. A cyclically movable ground-engaging structure according to any one of the preceding claims wherein the resiliently deformable body is of a laminate construction.

37. A cyclically movable ground-engaging structure according to claim 36 wherein the resiliently deformable body comprises an inner portion for positioning on a cyclically movable support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed as layers of materials having different hardness characteristics.

38. A cyclically movable ground-engaging structure according to claim 37 wherein the outer portion is of elastomeric material having wear resistance charact ristics suitable to provide a tread structure such as rubber having a hardness of about 63 to 65 Shore A.

39. A cyclically movable ground-engaging structure according to claim 37 or 38 wh rein th int rm diate layer is of elastomeric material suitable to provide load support and cushioning, such as rubber having a hardness of about 70 to 75 Shore A.

40. A cyclically movable ground-engaging structure according to claim 37 or 38 wherein the inner portion is formed of elastomeric material of a hardness suitable for gripping engagement with the cyclically movable support.

41. A cyclically movable ground-engaging structure according to claim 40 wherein the inner portion comprises elastomeric material such as rubber having a hardness of about 85 to 90 Shore A.

42. A cyclically movable ground-engaging structure according to claim 40 wherein the inner portion comprises a substantially rigid band such as a steel ring.

43. A cyclically movable ground-engaging structure according to claim 40, 41 or 42 wherein the inner portion is of a split construction so that it can expand and contract to facilitate installation onto the support.

44. A cyclically movable ground-engaging structure according to claim 43 wherein the inner portion comprises a plurality of segments positioned in circumferential relationship such that the segments can move into a circumferentially spaced relationship upon expansion of the inner portion.

45. A ground-engaging segment which along with other such segments can be assembled to form a ground-engaging structure according to any one of the preceding claims.

46. A ground ngaging segment comprising a resili ntly deformable body having provided therein a cavity bounded by a cavity wall, the cavity being

arranged to assume a cross-sectional configuration upon resilient deformation of the body und r normal static load conditions, wherein said configuration inhibits formation of zones of high stress concentration at the cavity wall.

47. A ground-engaging segment according to claim 46 wherein the cross-sectional configuration assumed by the cavity upon the resilient deformation of the body comprises a closed curve.

48. A ground-engaging segment according to claim 46 or 47 wherein the cavity is arranged to assume said cross-sectional configuration upon resilient deformation of the body through formation of the cavity in a suitable cross-sectional shape in the undeformed condition of the body.

49. A ground-engaging segment according to claim 48 wherein the cavity comprises a longitudinal cavity having a cross-sectional shape which is rounded without being circular.

50. A ground-engaging segment according to claim 48 wherein the cross-section of the cavity is generally triangular with rounded corners.

51. A ground-engaging segment according to claim 48 wherein the cross-section of the cavity is generally polygonal with rounded corners.

52. A ground-engaging segment according to claim 50 or 51 wherein at least one side of the triangle or polygon is arcuate.

53. A cyclically movable ground-engaging structure according to claim 48 wherein the cross-section of the cavity comprises a closed curve.

54. A ground-engaging segm nt according to claim 48 wherein the cross-section of the cavity comprises a pair of spaced apart arcs with the

concave sid s ther of in facing r lationship and int rmediat lines xtending between the arcs.

55. A ground-engaging segment according to claim 54 wherein said arcs have radii of curvature which are unequal.

56. A ground-engaging segment according to claim 54 or 55 wherein said lines extending between the arcs are curved.

57. A ground-engaging segment according to claim 56 wherein the cross-section of the cavity is an ellipse or ovoid.

58. A ground-engaging segment according to any one of claims 46 to 57 wherein the undeformed condition of the body, the cavity is elongate in cross-section in the undeformed condition of the body.

59. A ground-engaging segment according to claim 58 wherein the elongate cavity is so disposed that the major axis of the cross-sectional shape of the cavity is substantially normal to the direction of cyclical movement of the ground-engaging structure.

60. A ground-engaging segment according to any one of claims 46 to 59 wherein the cavity has two opposed end portions in cross-section which are aligned with a direction substantially normal to the direction of cyclical movement of the ground-engaging structure.

61. A ground-engaging segment according to claim 60 wherein one of the end portions is enlarged with respect to the other.

62. A ground-engaging segment according to any one of claims 46 to 61 wherein the cavity pens nto th xt rior of the body and extends into th body.

63. A cyclically movabl ground-engaging structure according to claim 62 wherein the cavity extends cross-wise through the body with both ends of the cavity opening on to the exterior of the body.

64. A cyclically movable ground-engaging structure according to claim 63 wherein the cavity is open at one end and closed at the other end.

65. A cyclically movable ground-engaging structure according to claim 62 wherein the cavity is open at both ends and closed internally.

66. A cyclically movable ground-engaging structure according to any one of claims 46 to 65 wherein the cavity comprises a core hole.

67. A cyclically movable ground-engaging structure according to any one of claims 46 to 66 wherein the body is provided with a plurality of said cavities.

68. A cyclically movable ground-engaging structure comprising an annular body having an inner portion for positioning on a support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed as layers of materials having different hardness characteristics.

69. A segment for a cyclically movable ground-engaging structure, said segment comprising a body having an inner portion for positioning on a support, an outer portion disposed outwardly of the inner portion for engaging the ground, and a resiliently deformable intermediate portion between the inner and outer portions, wherein the inner, intermediate and outer portions are formed of mat rials having different hardness characteristics.

70. A cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a plurality of caviti s in circumferentially spaced apart relationship, the cavities each having a cross-section which is elongate and of substantially constant orientation throughout the body.

71. A cyclically movable ground-engaging structure according to claim 70 wherein the elongate cross-section of each of said cavities has a major axis and wherein the cavity is oriented such that the major axis of the cross-section thereof is substantially normal to the direction of cyclical movement.

72. A cyclically movable ground-engaging structure according to claim 71 wherein the cross-section of each of said cavities comprises two opposed end portions in opposed relationship along said major axis, wherein each of said end portions comprises an arc.

73. A cyclically movable ground-engaging structure according to claim 72 wherein the arcs have radii of curvature which are unequal.

74. A cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arranged in circumferentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from the inner surface, each of the cavities in the second set being aligned in a direction to the direction of cyclical movement with a respective one of the cavities in the first set.

75. A cyclically movable ground-engaging structure comprising a resiliently deformabl body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arrang d in circumf rentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced

apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from th inner surface, ach of the cavities in the second set being aligned in a direction normal of the direction of cyclical movement with a respective one of the cavities in the first set, the cavities in the first set being of a rounded configuration in cross-section and the cavities in the second set being circular in cross-section.

76. A cyclically movable ground-engaging structure comprising a resiliently deformable body having provided therein a plurality of cavities, said cavities comprising a first set of cavities arranged in circumferentially spaced apart relationship and a second set of cavities arranged in circumferentially spaced apart relationship the first set of cavities being positioned outwardly of the first set in the direction away from the inner surface, at least some of the cavities in at least one of the first and second sets being of non-circular cross-section.

77. A cyclically movable ground-engaging structure according to claim 76 wherein said at least some of the cavities are of a rounded configuration in cross-section.

78. A cyclically movable ground-engaging structure according to claim 76 or 77 wherein said at least some of the cavities are of an elongate cross-section.

79. A cyclically movable ground-engaging structure according to claim 78 wherein the elongate cross-section has a major axis and wherein the respective cavities are oriented such that each has the major axis of the cross-section thereof substantially normal to the direction of cyclical movement of the ground-engaging structure.

80. A cyclically movable ground-engaging structure according to any one of claims 70 to 75 of composite construction comprising a plurality of ground-engaging segments.

81. A gr und-engaging segm nt for assembly along with other such segments to provide a composite ground-engaging structure according to claim 80.

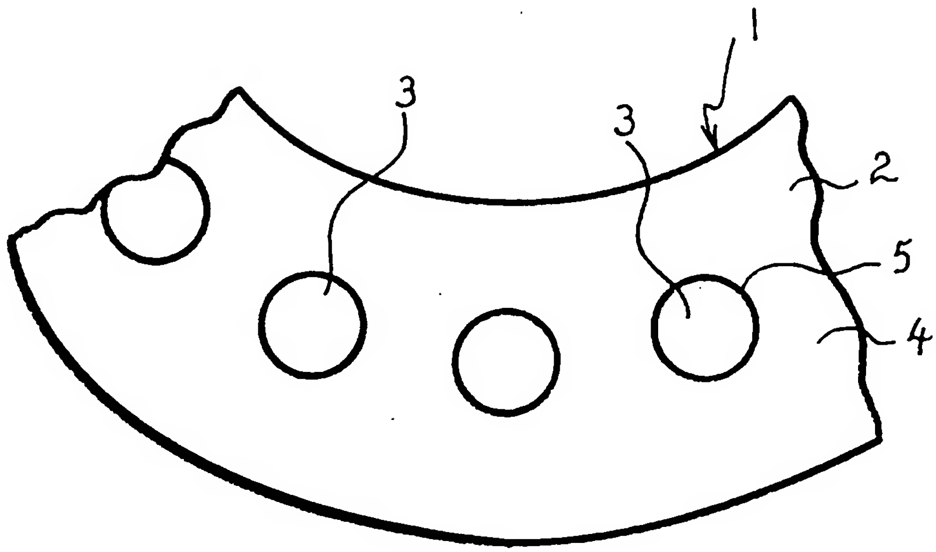


Fig. 1. (Prior Art)

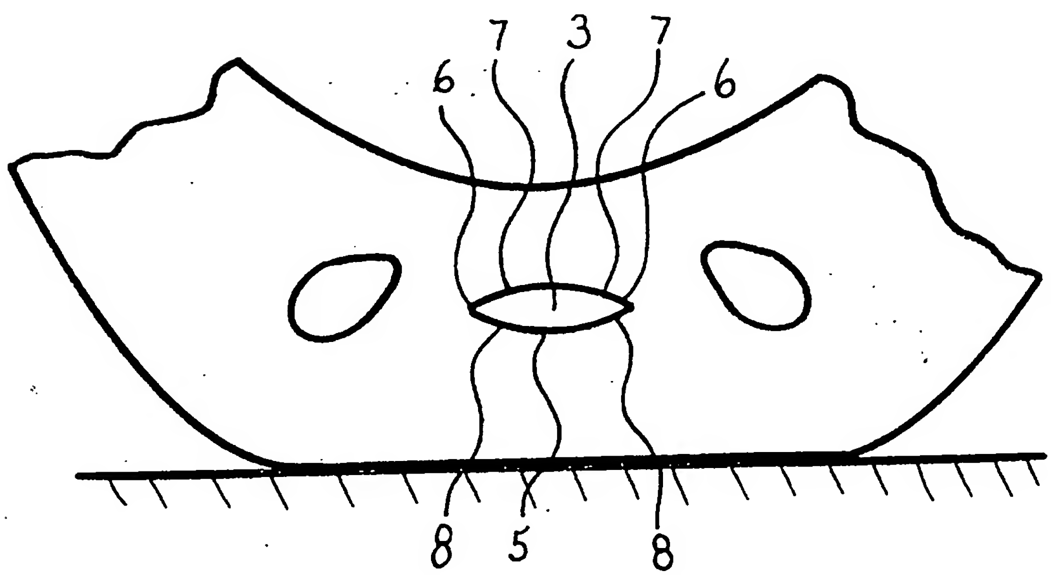


Fig. 2. (Prior Art)

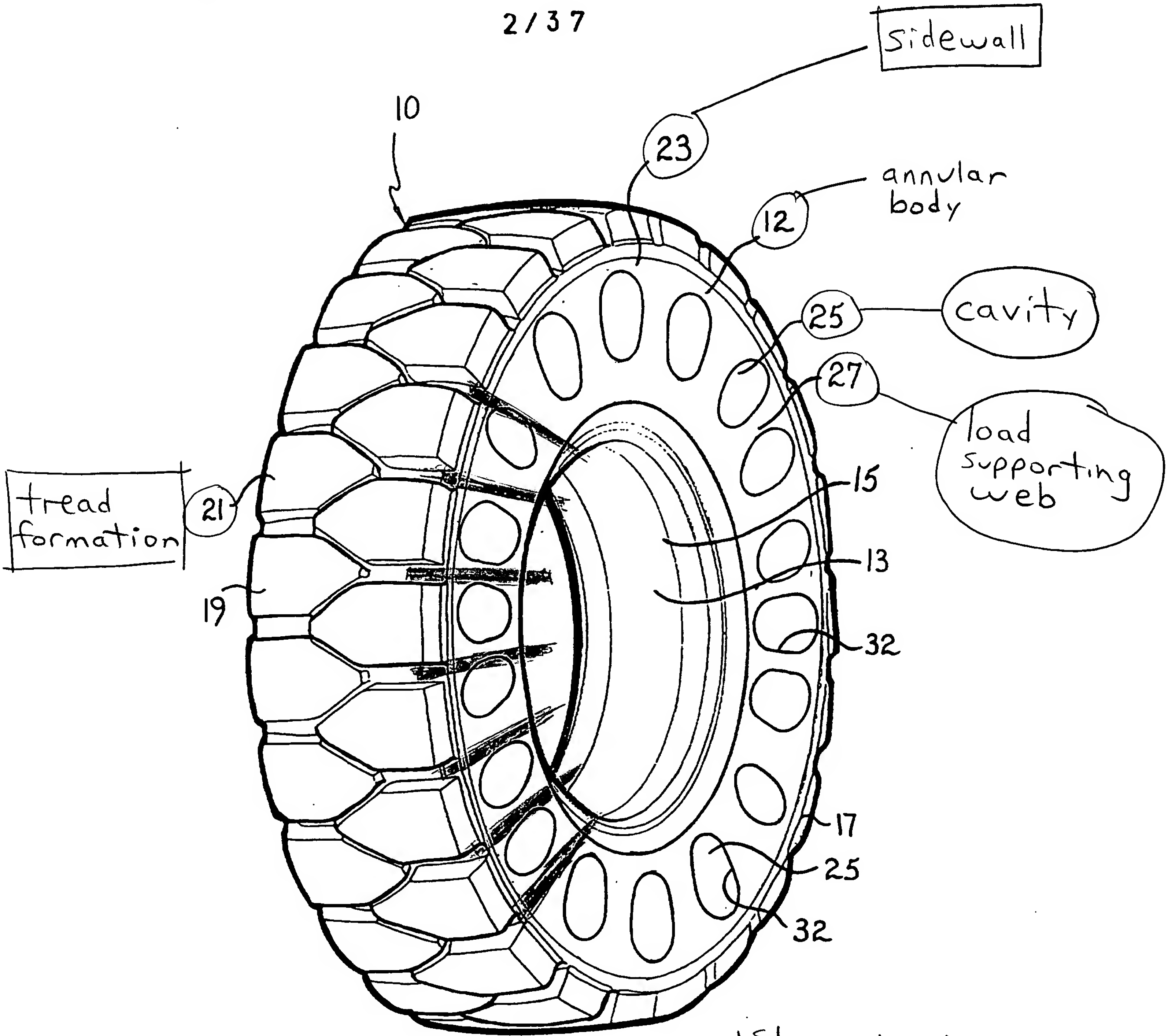


FIG. 3.

1st embodiment one-piece construction

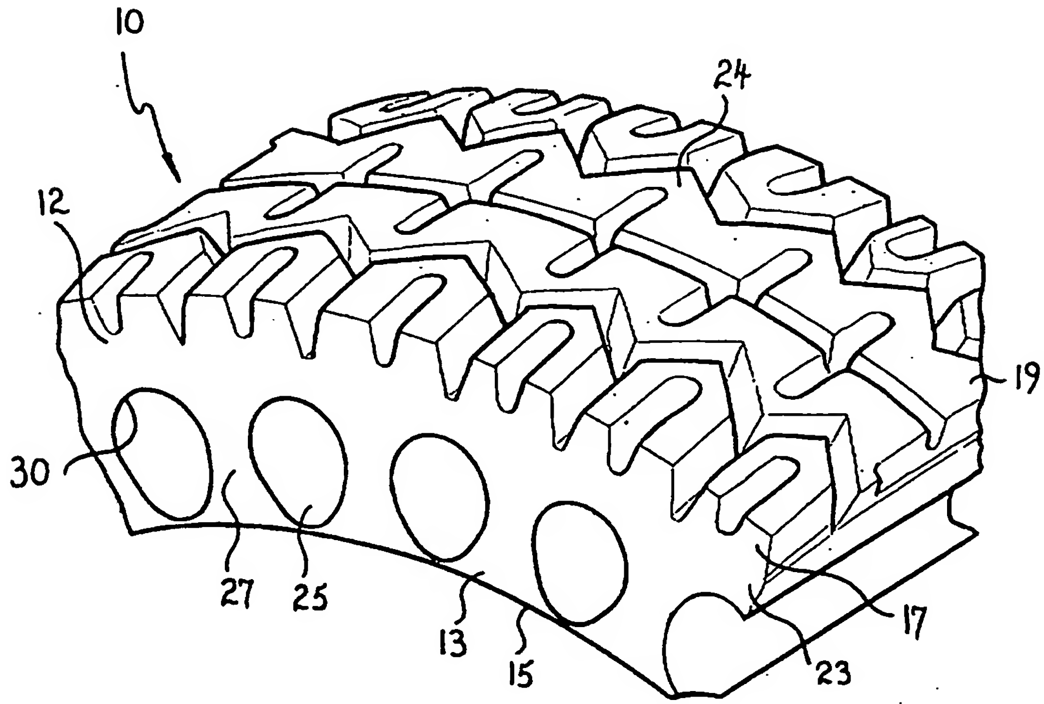


Fig. 4.

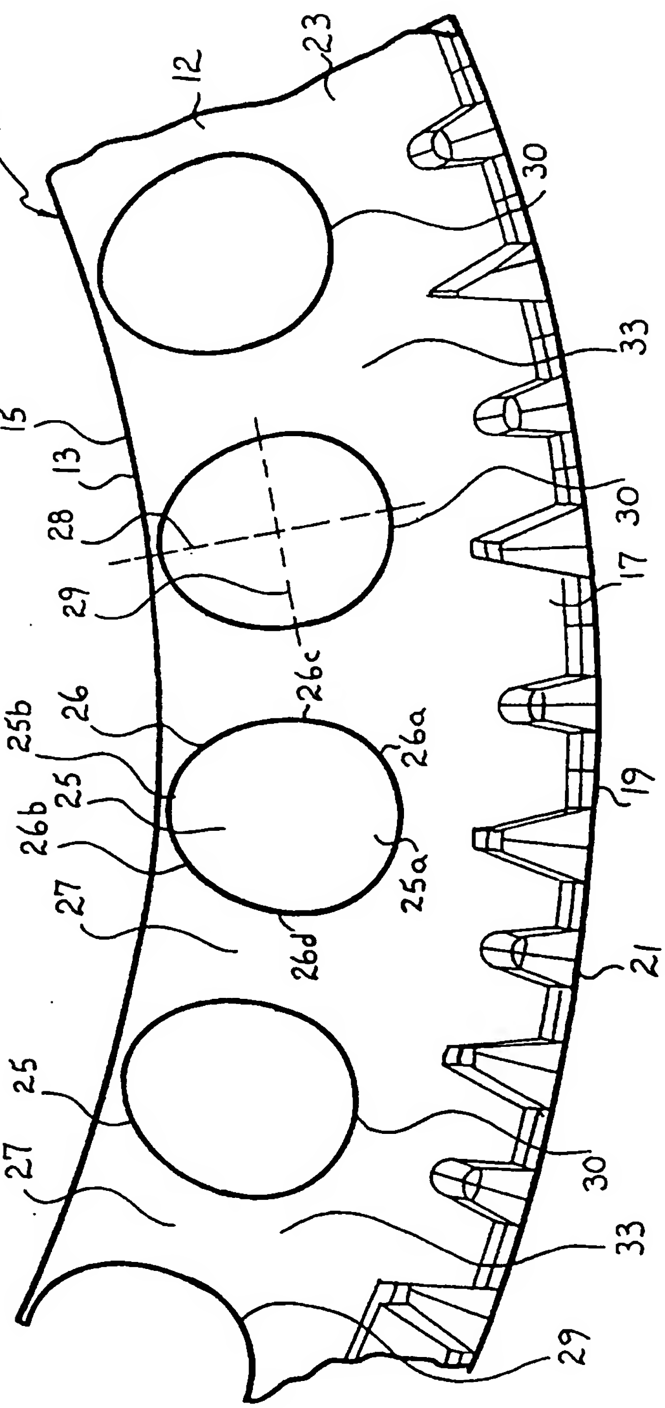

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Fig. 5.

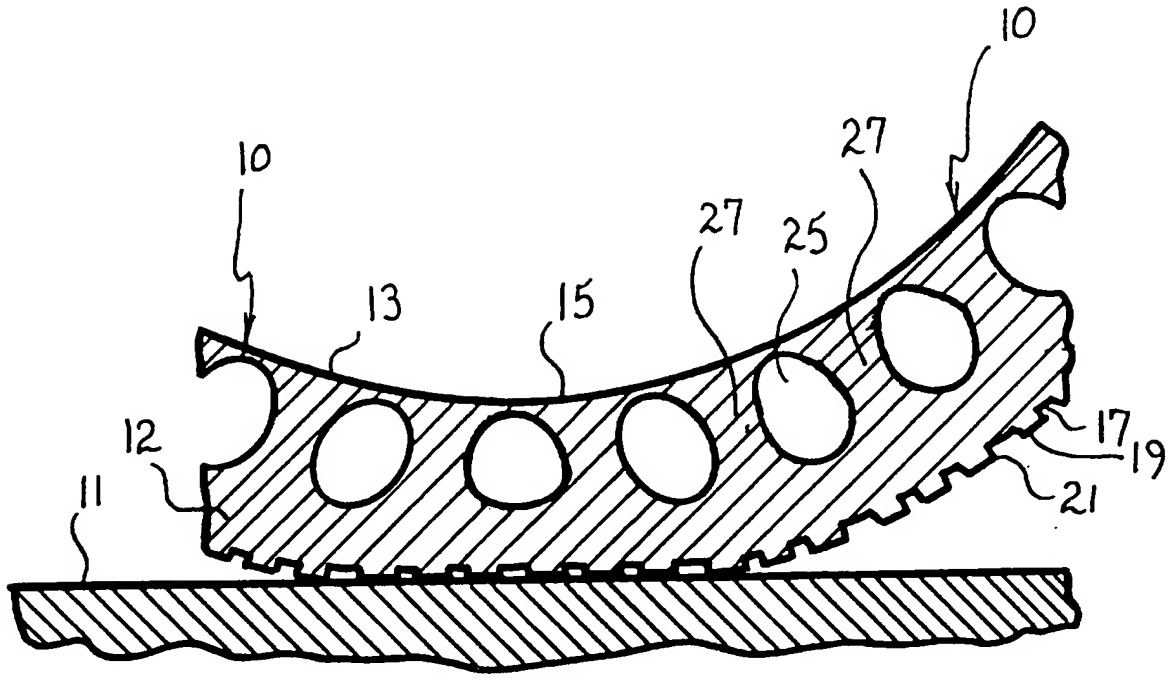

Fig. 6.

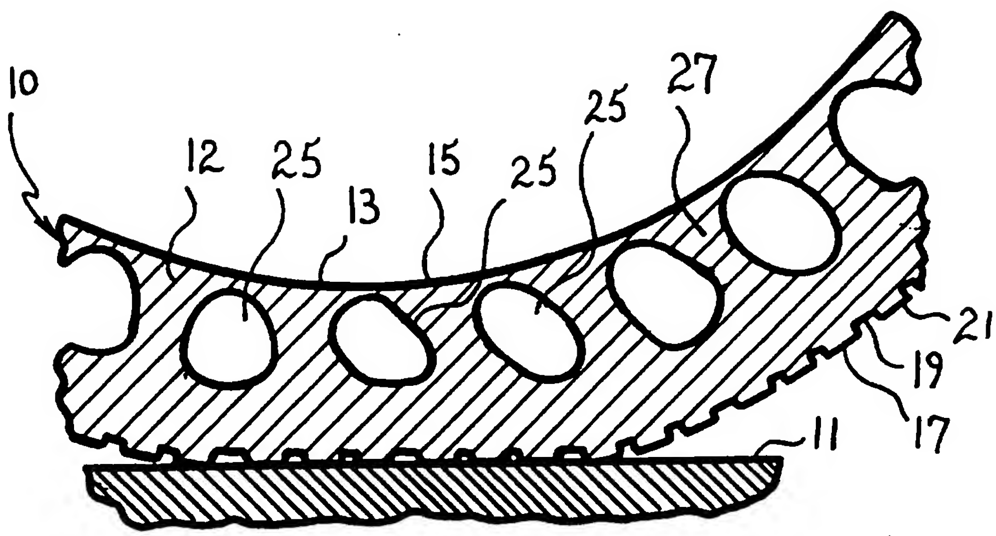

Fig. 7

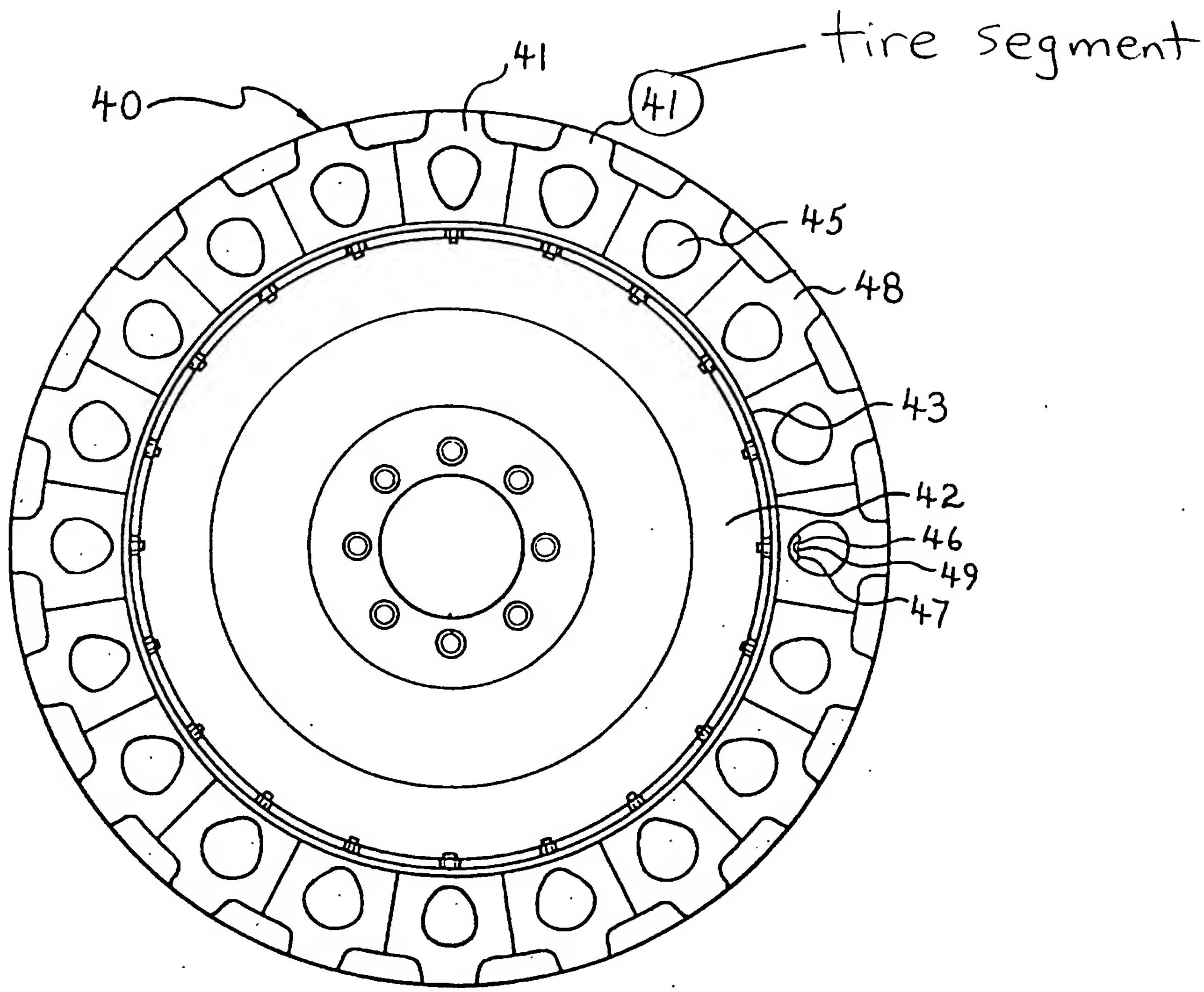

FIG. 8 2nd embodiment tire segments

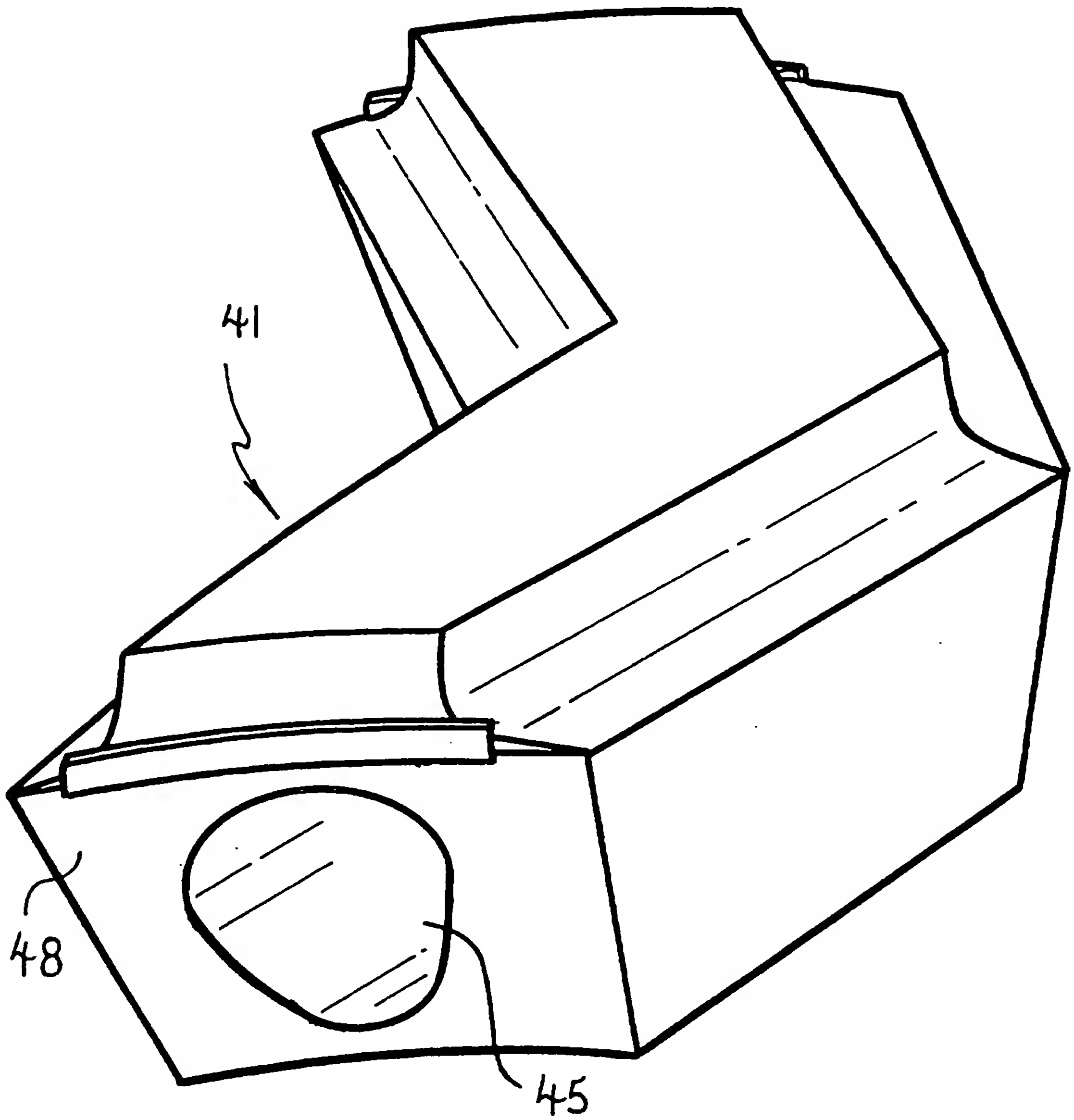

Fig. 9.

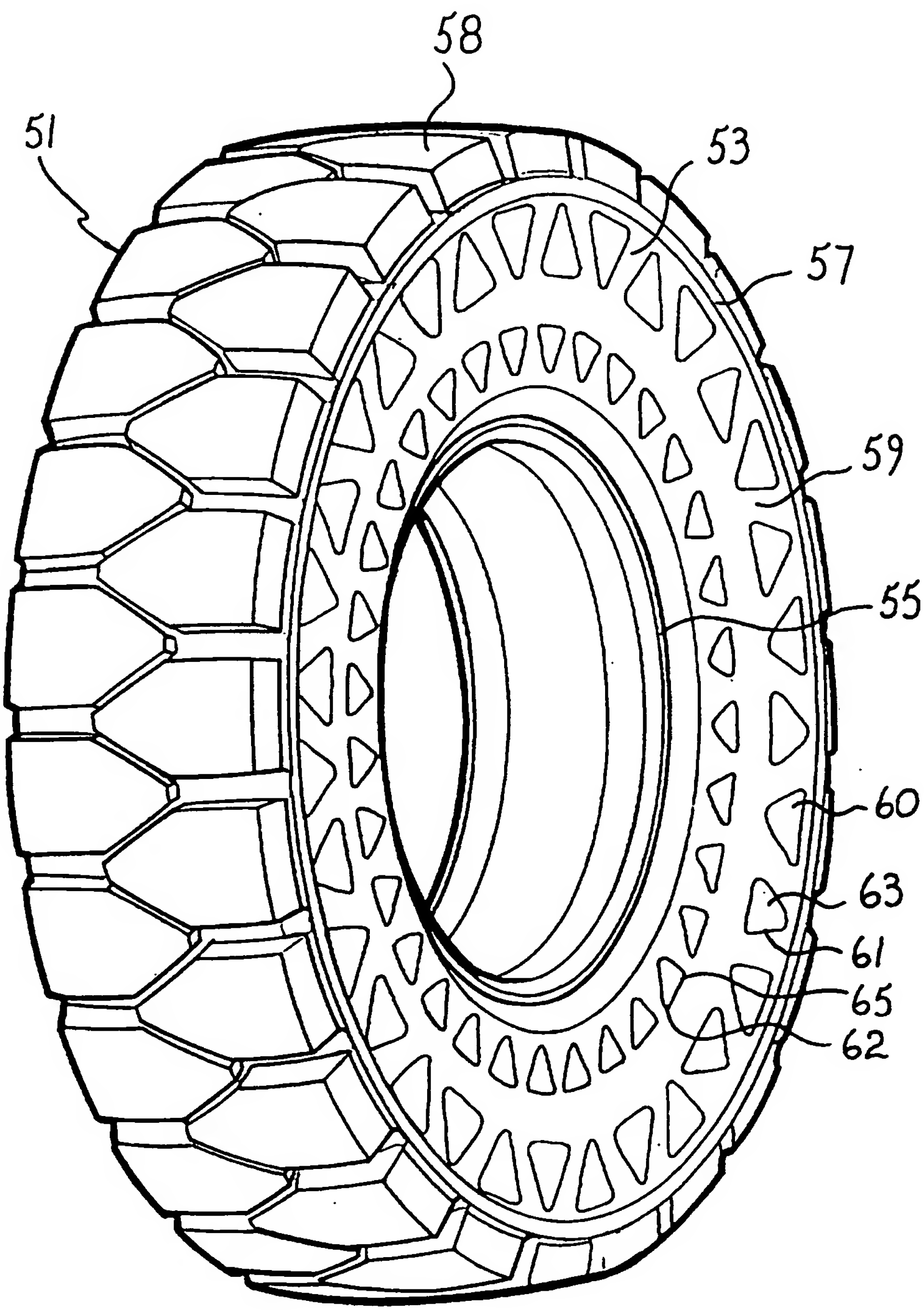

Fig 10.

third embodiment
two sets of
Cavitres

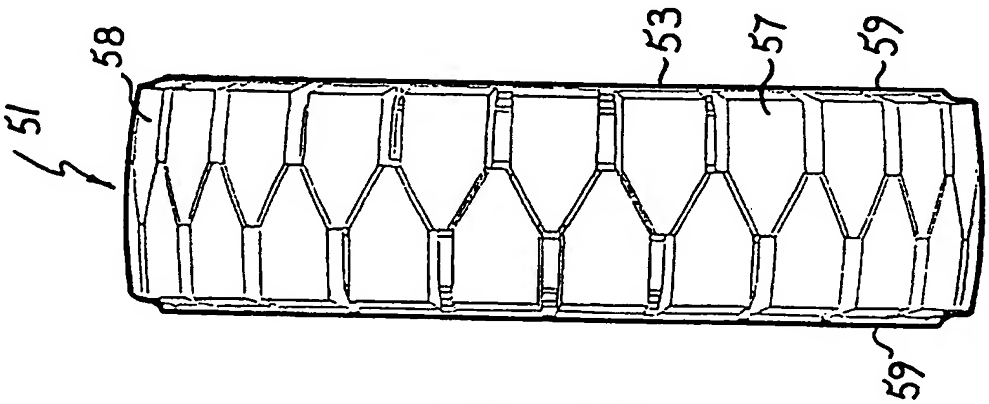
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Fig 12

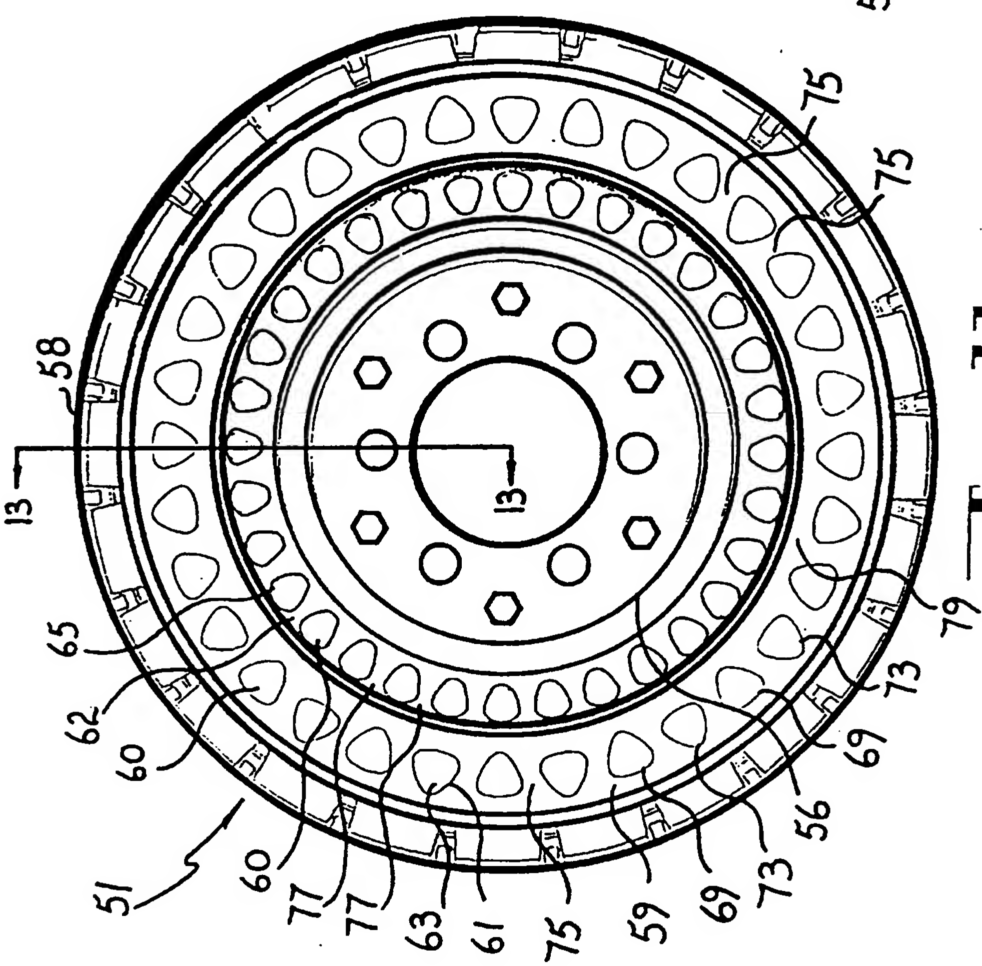
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Fig 11

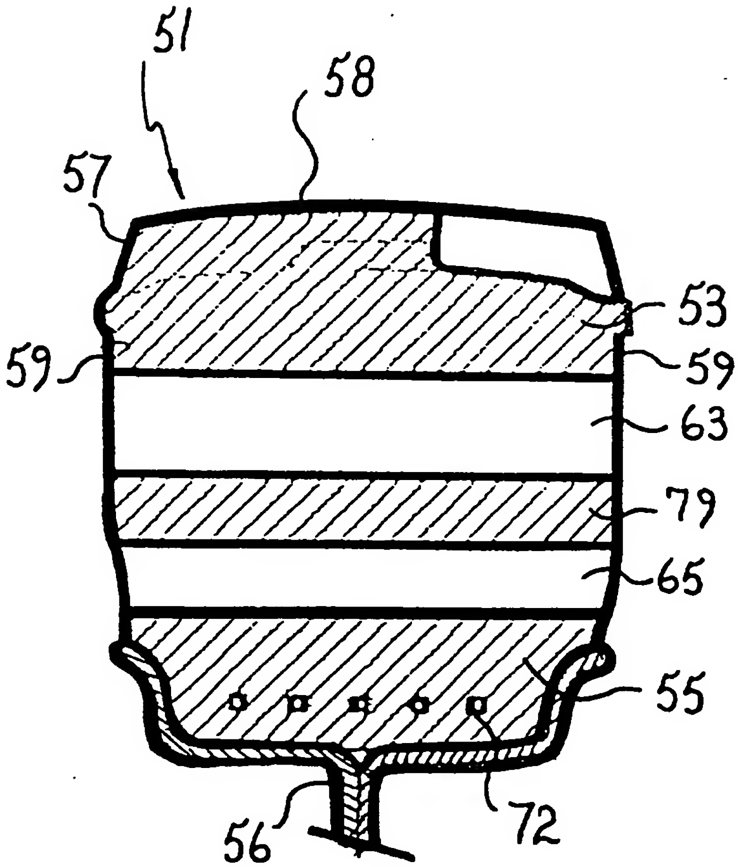


Fig. 13.

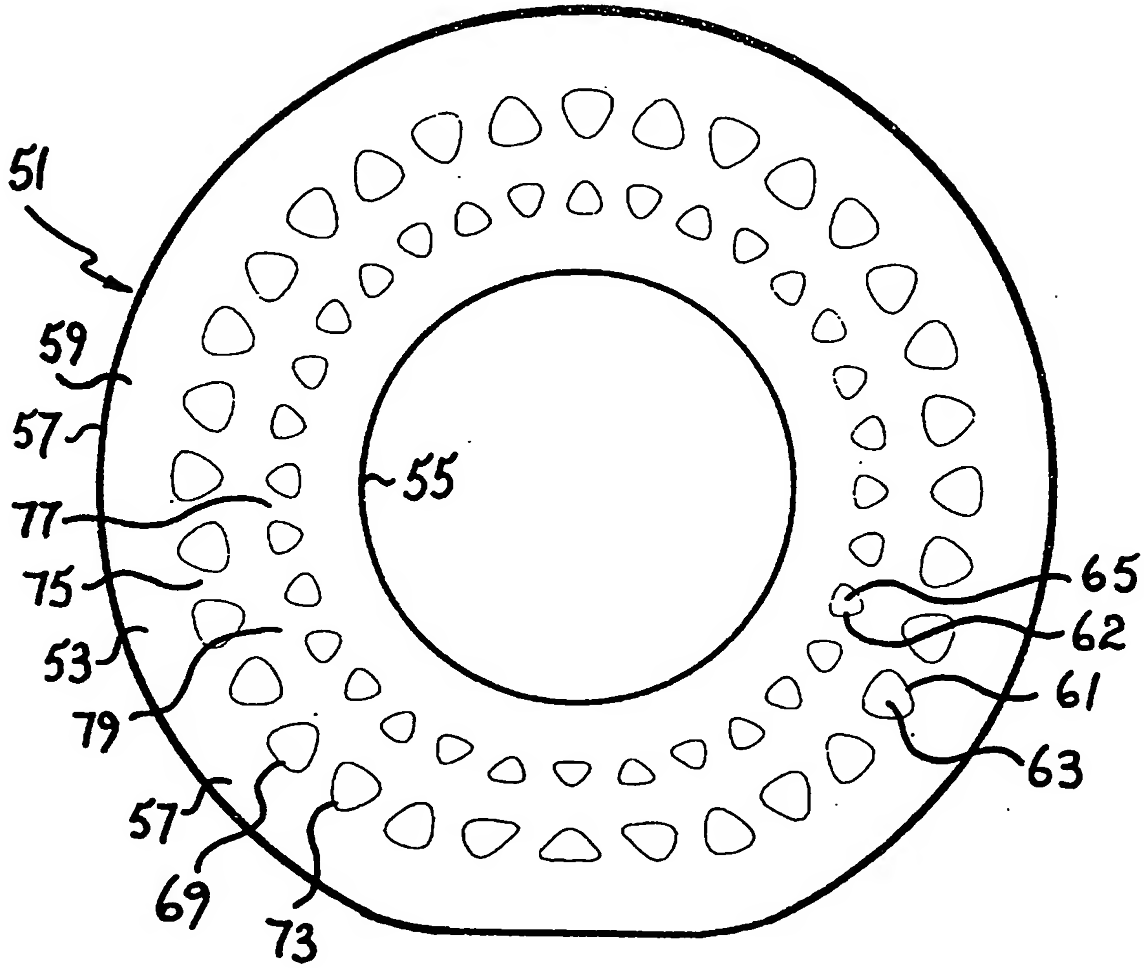


Fig 14.

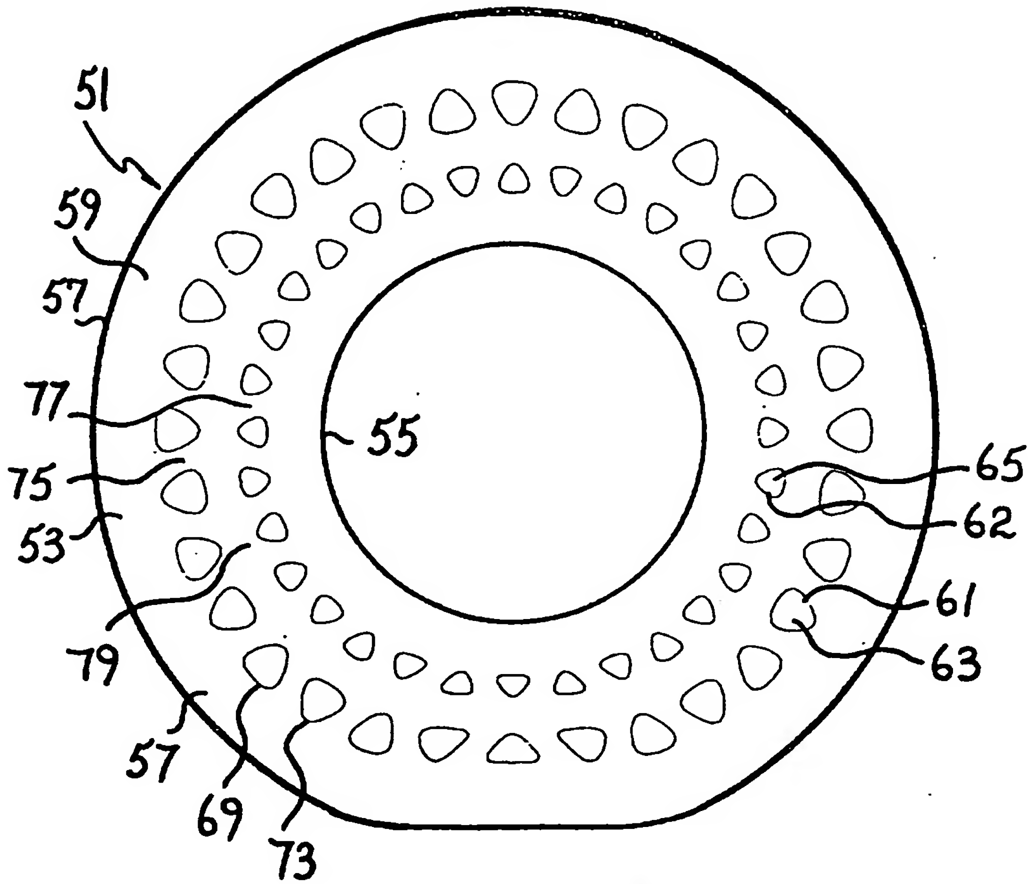


Fig. 15.

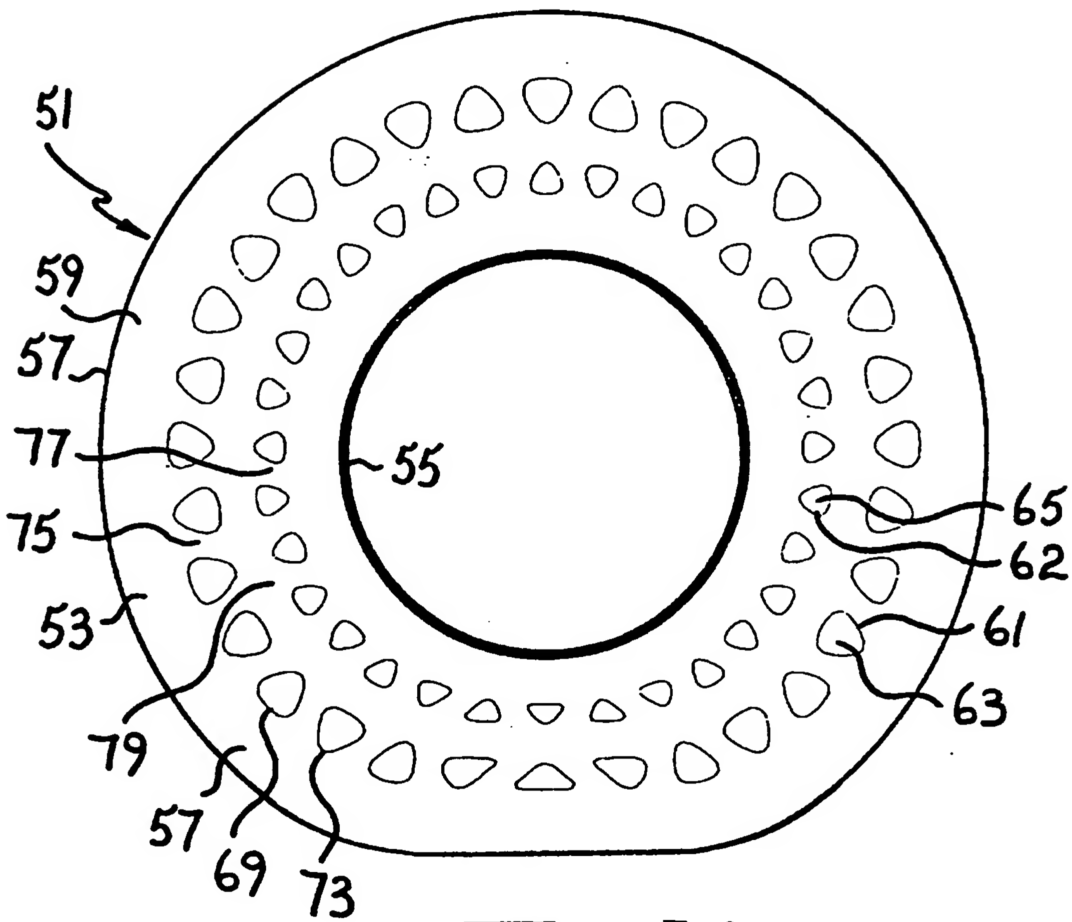


Fig 16.

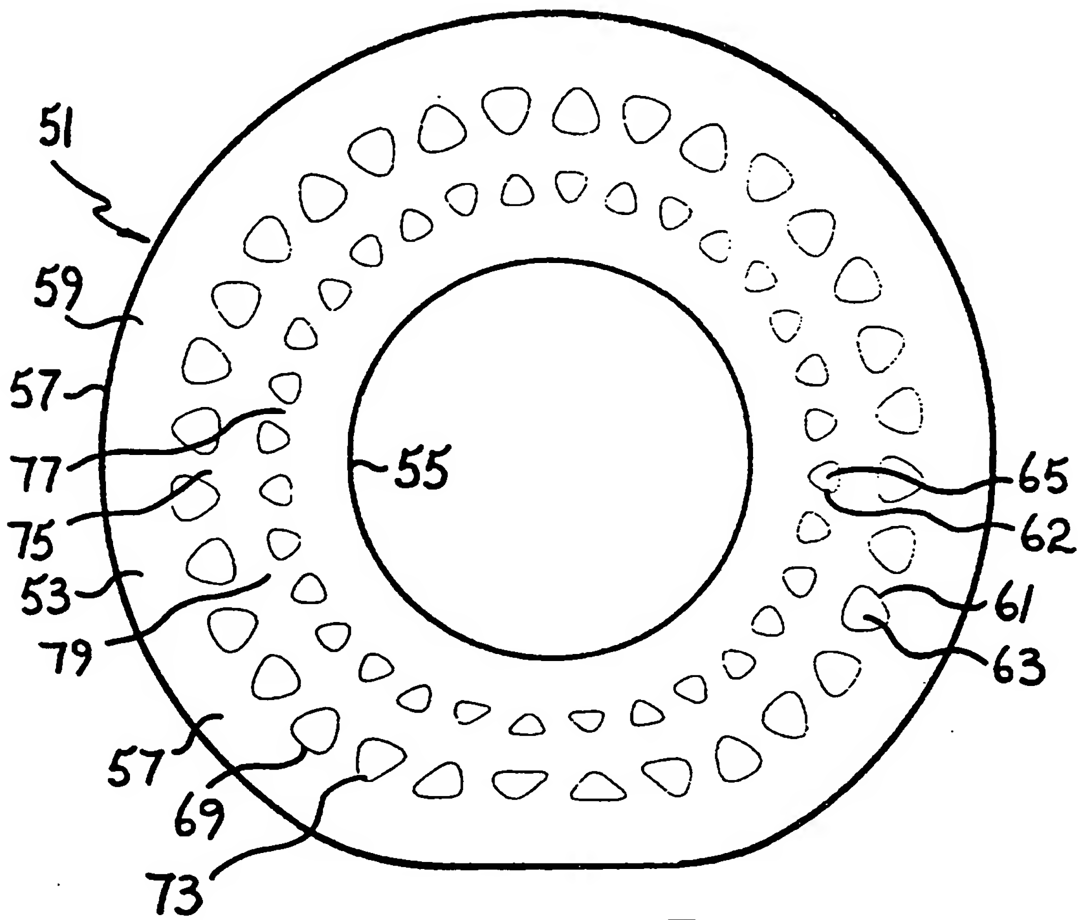


Fig 17

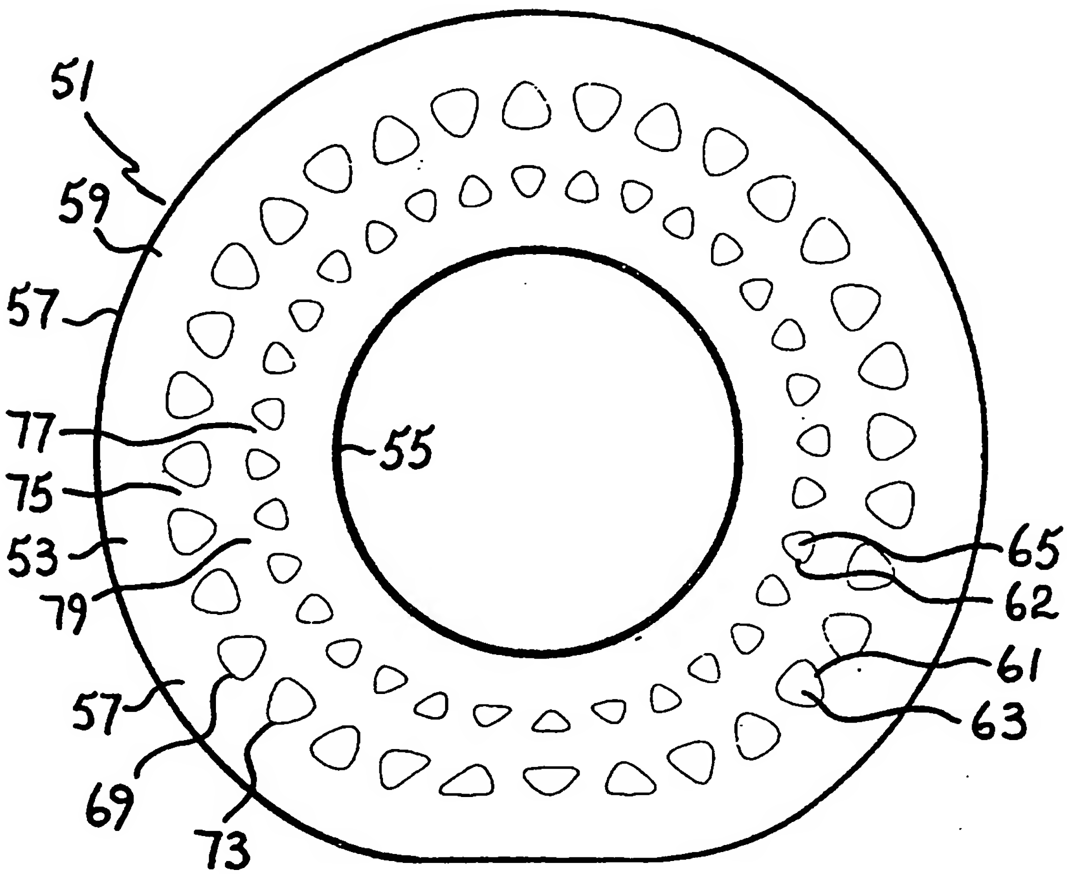


Fig. 18.

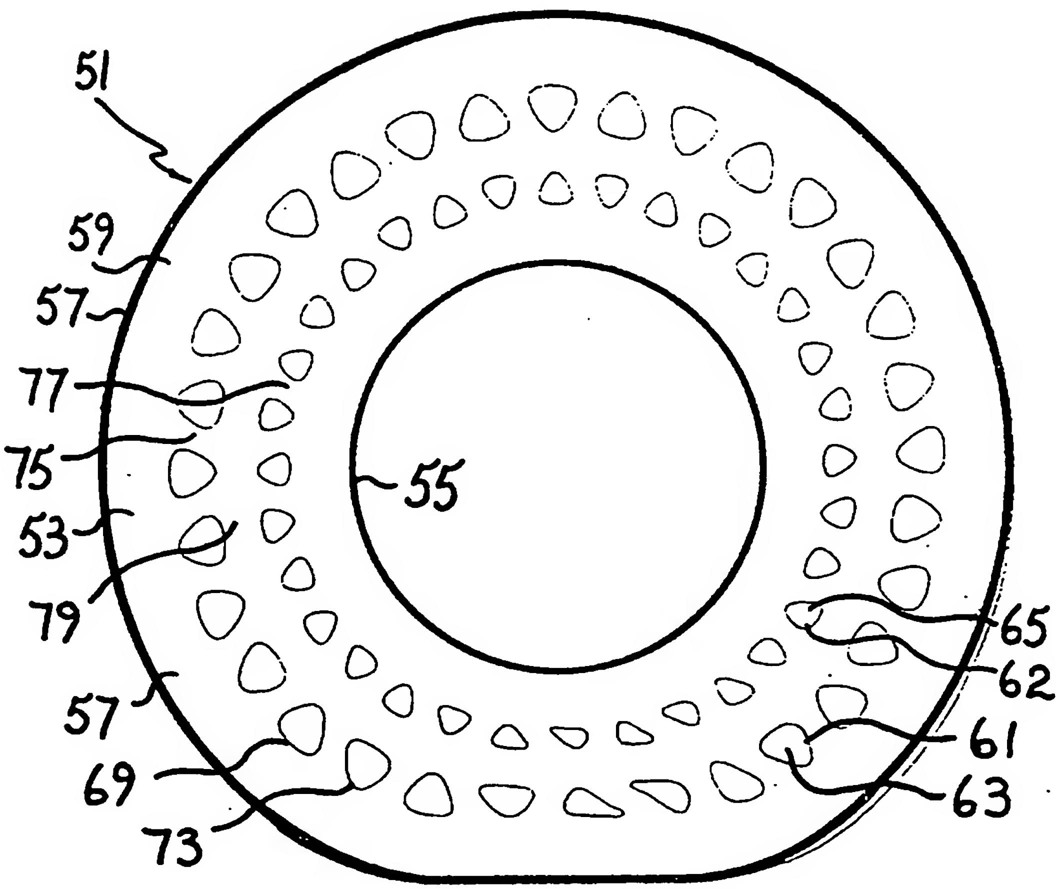


Fig 19

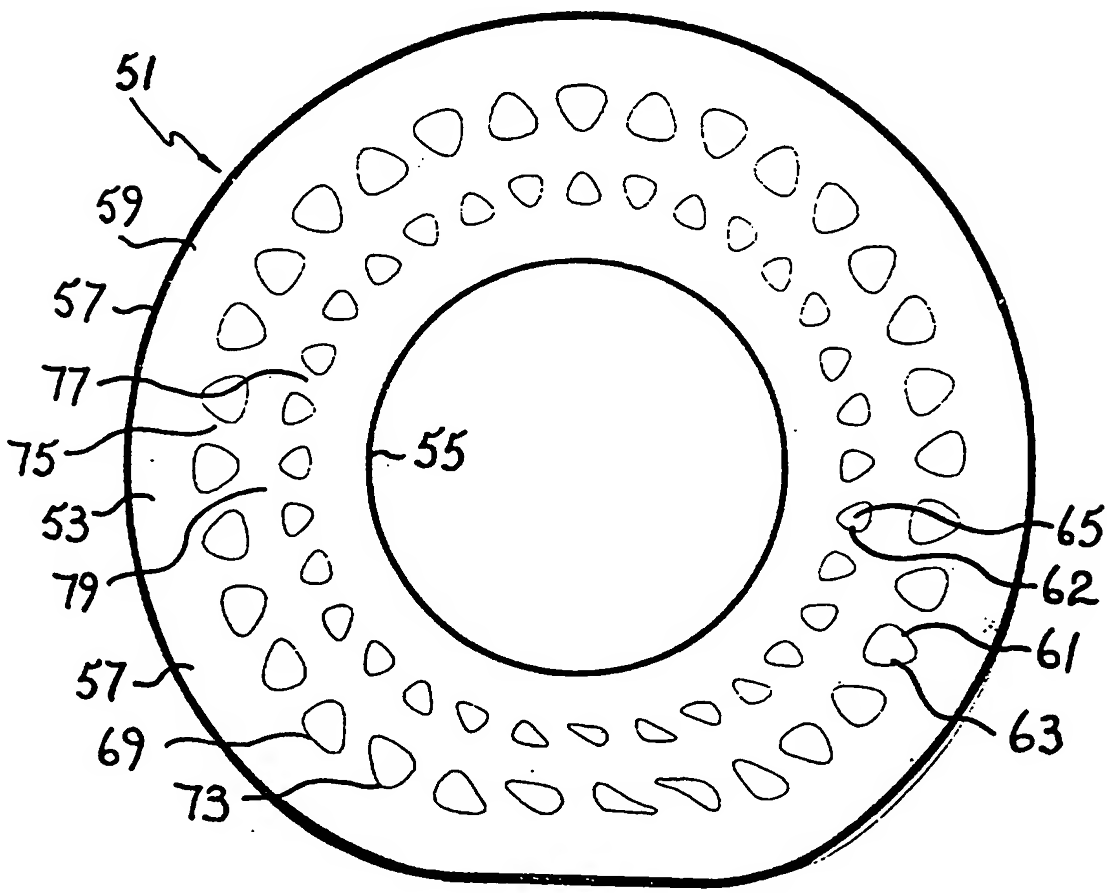


Fig 20

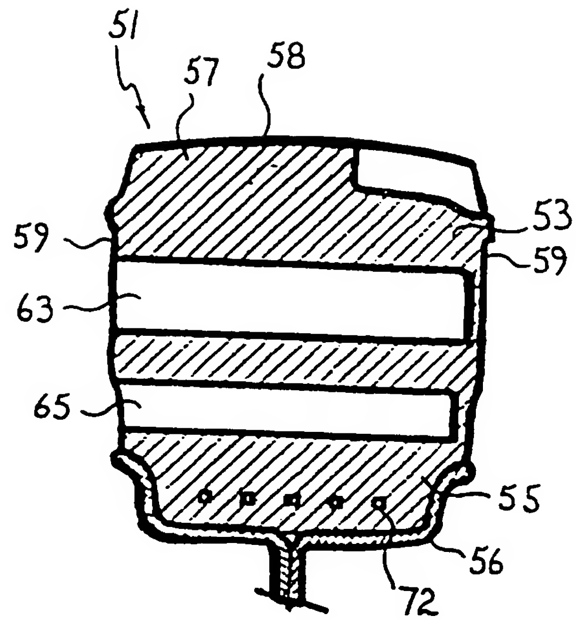
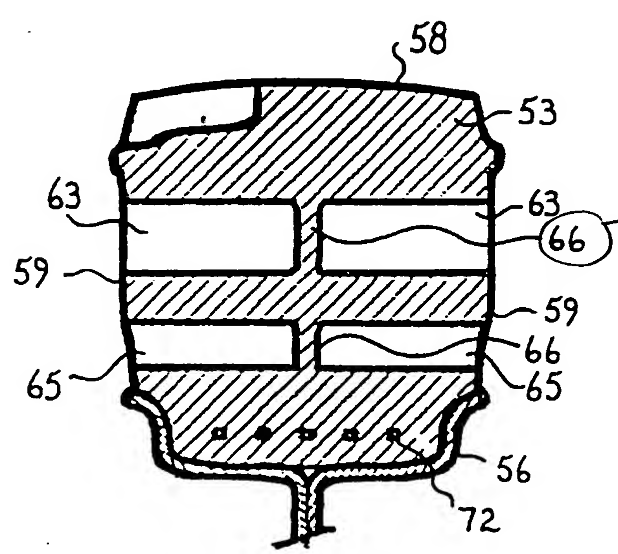


Fig 21

Cavities open to one side only



partition

Fig 22

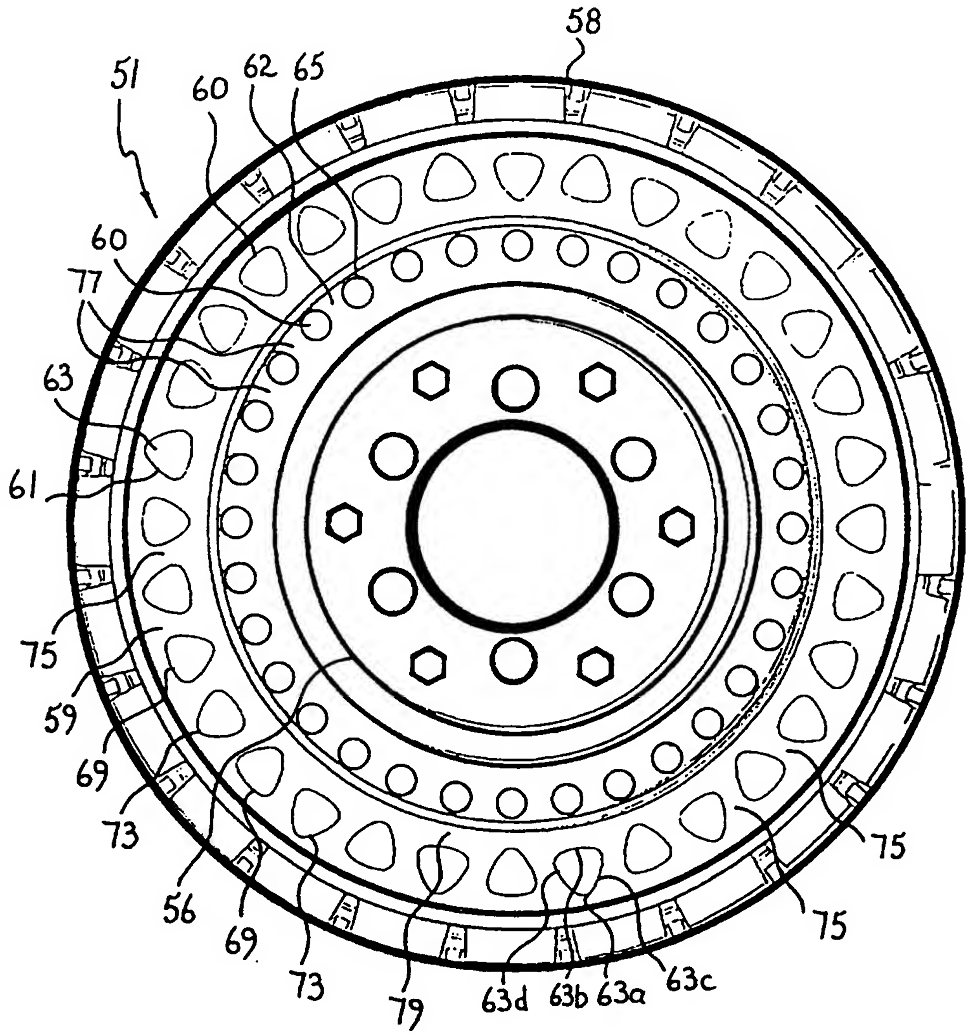

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Fig 23

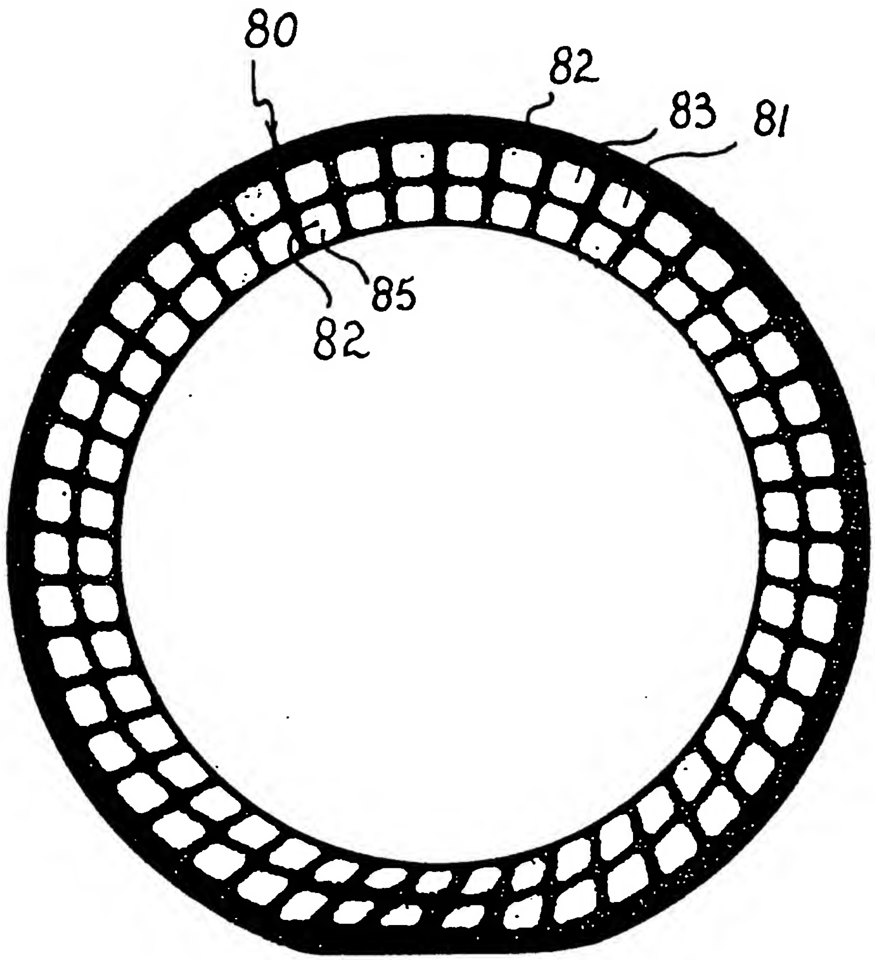


Fig. 24.

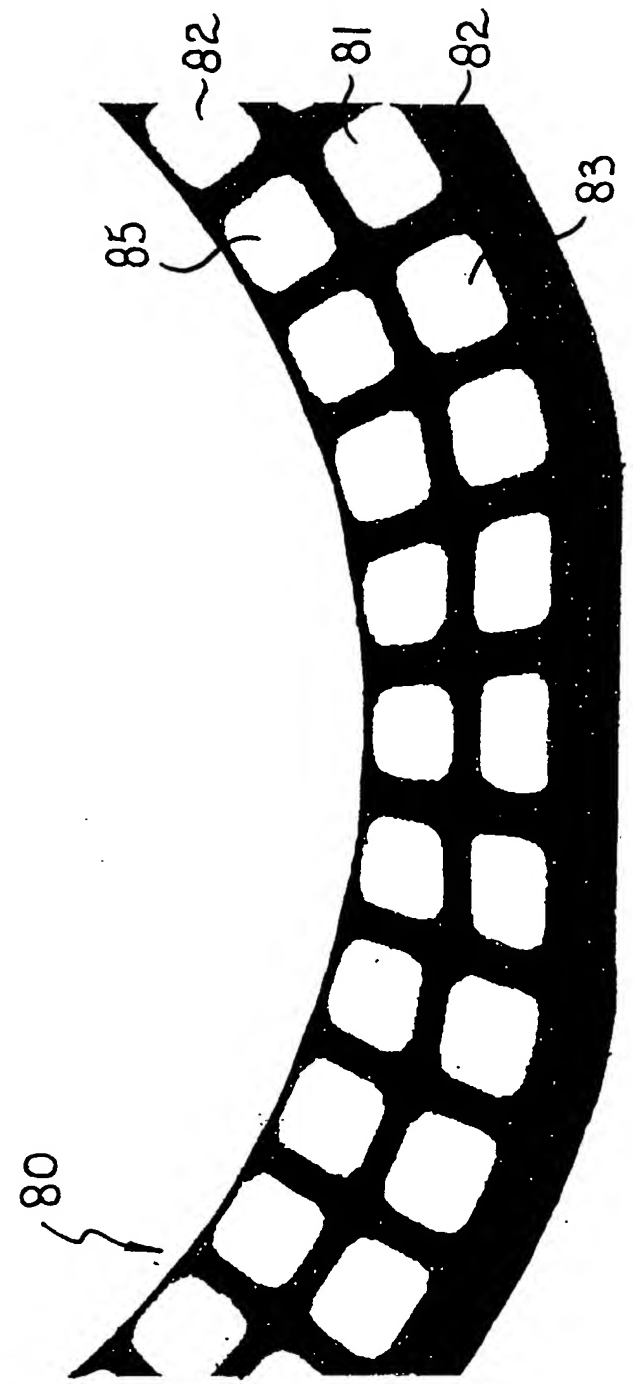


Fig 25

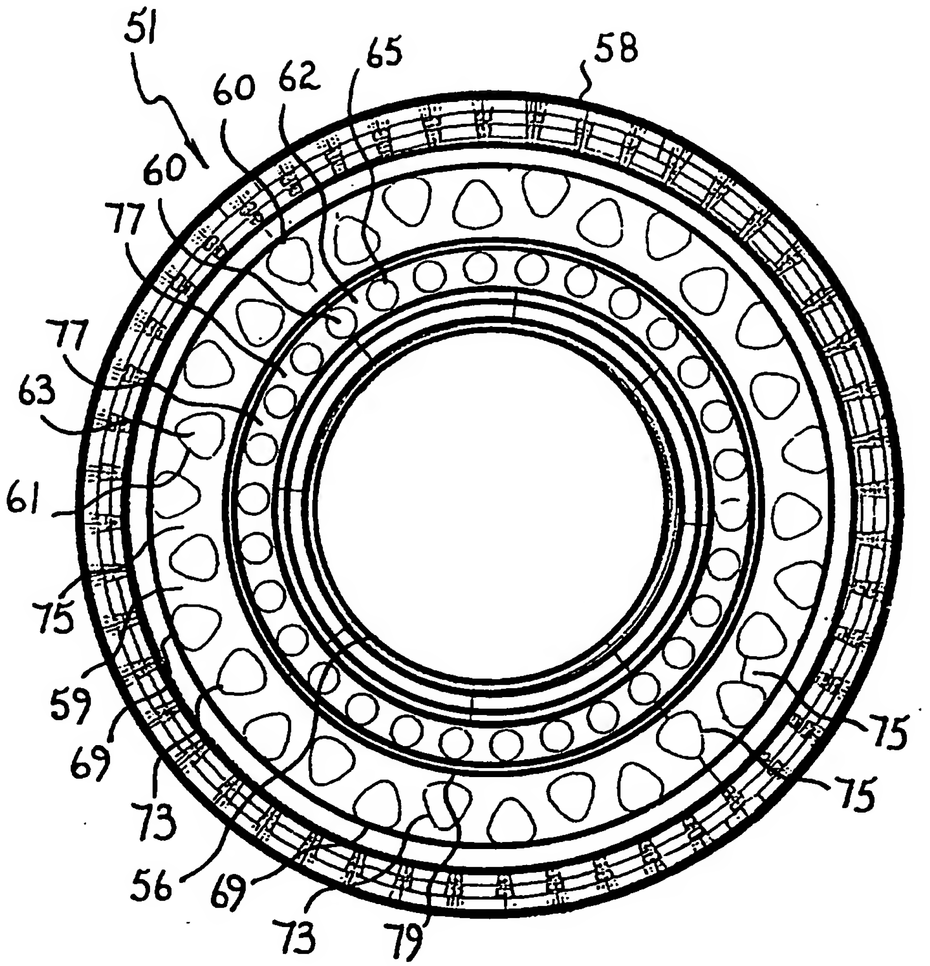


Fig.26.

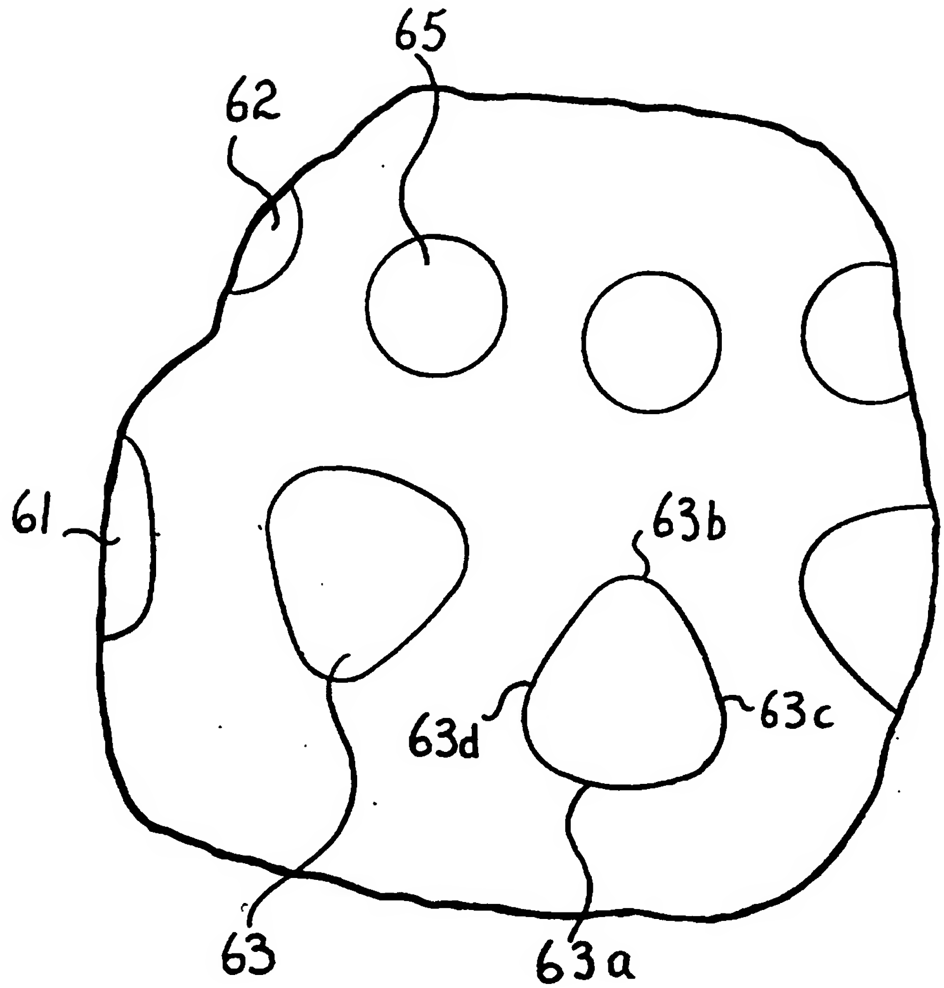


Fig.27.

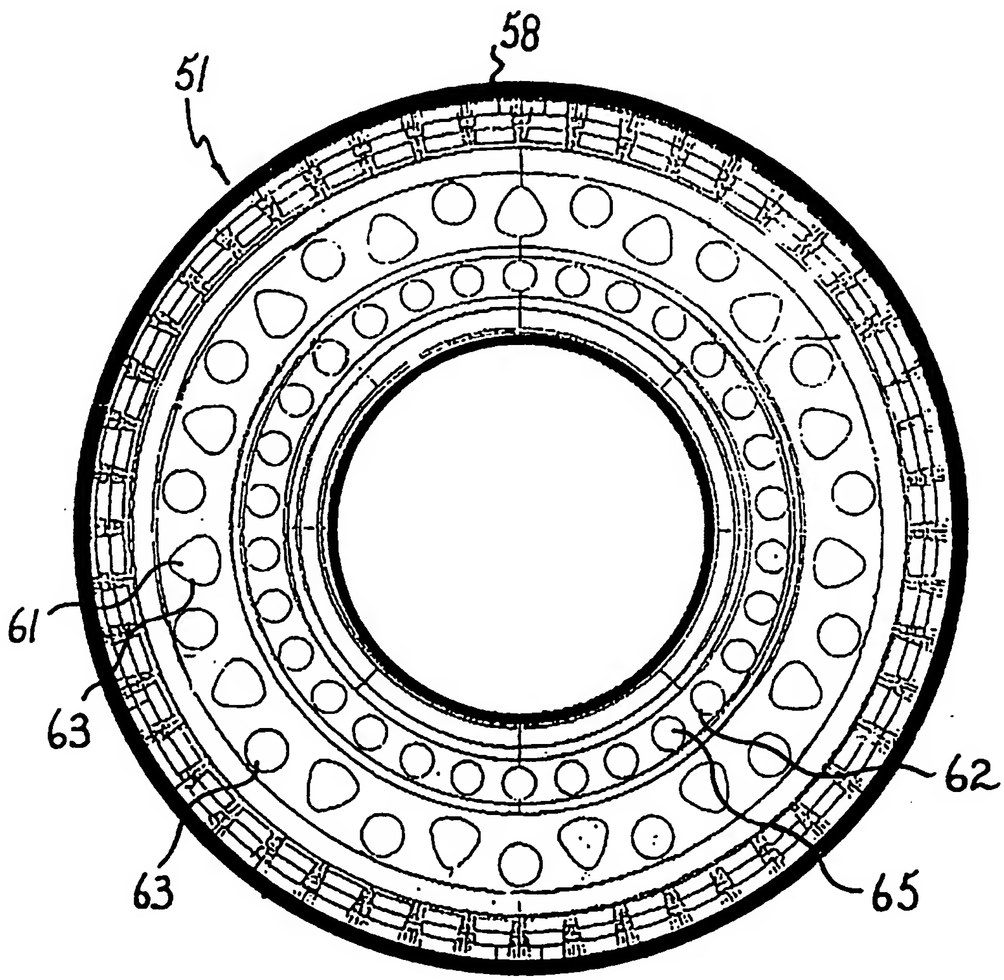


Fig 28.

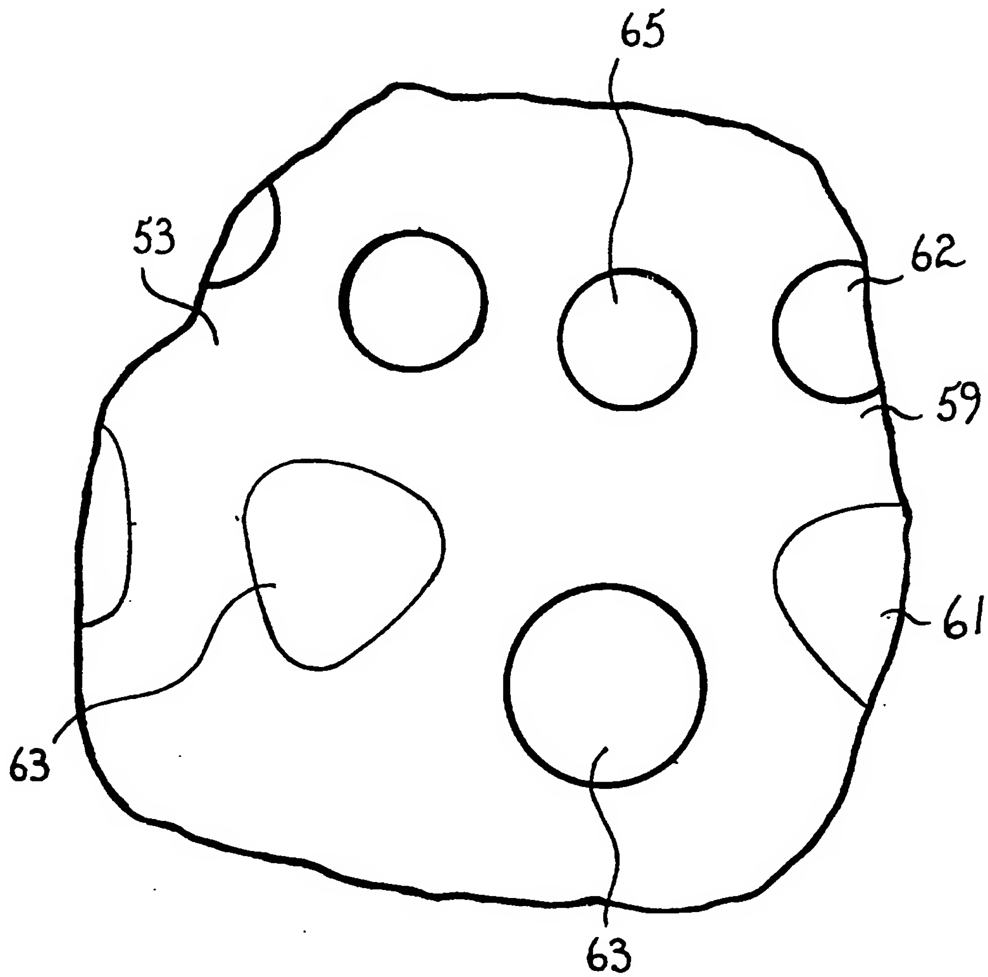


Fig 29

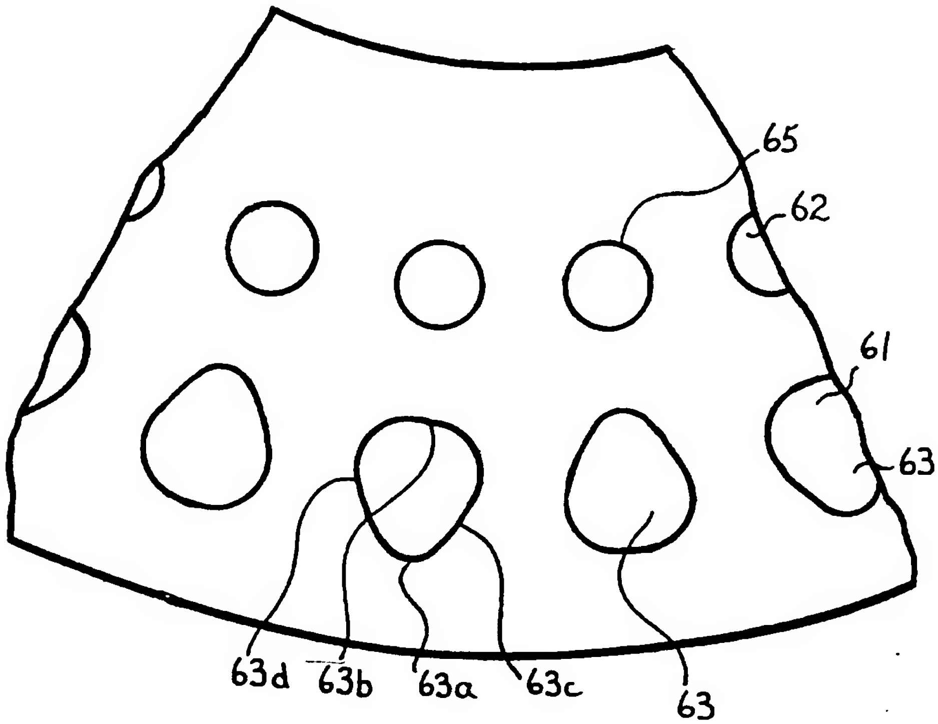


Fig.30

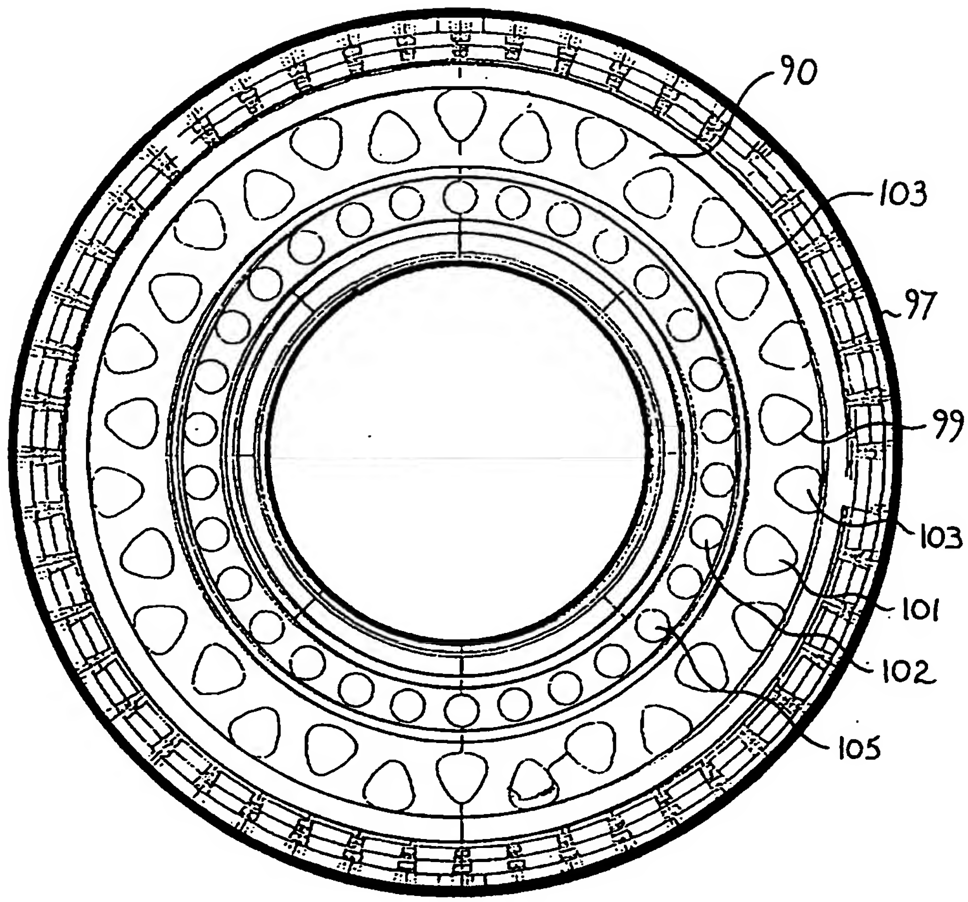
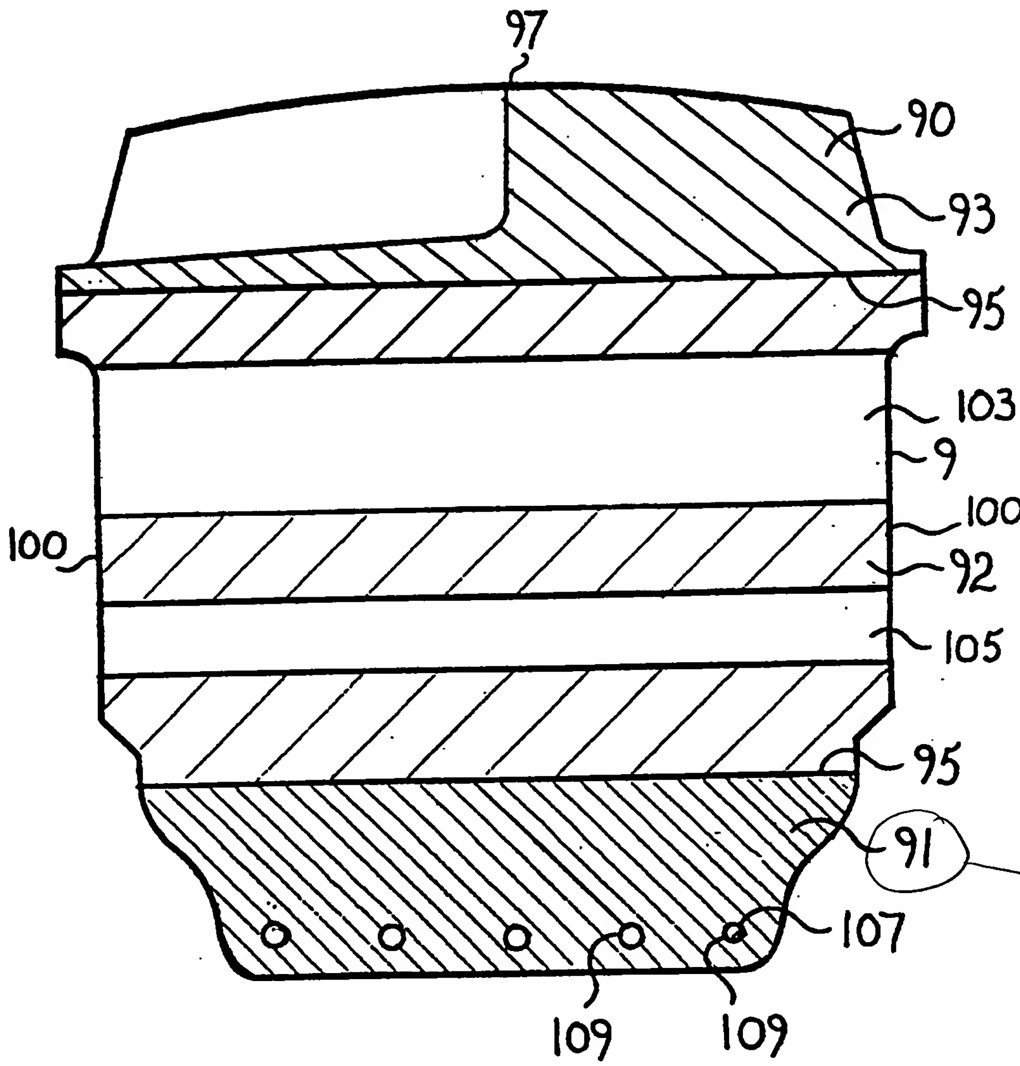


Fig.31.



inner layer

greater stiffness to facilitate gripping of tire on rim

Fig. 32.

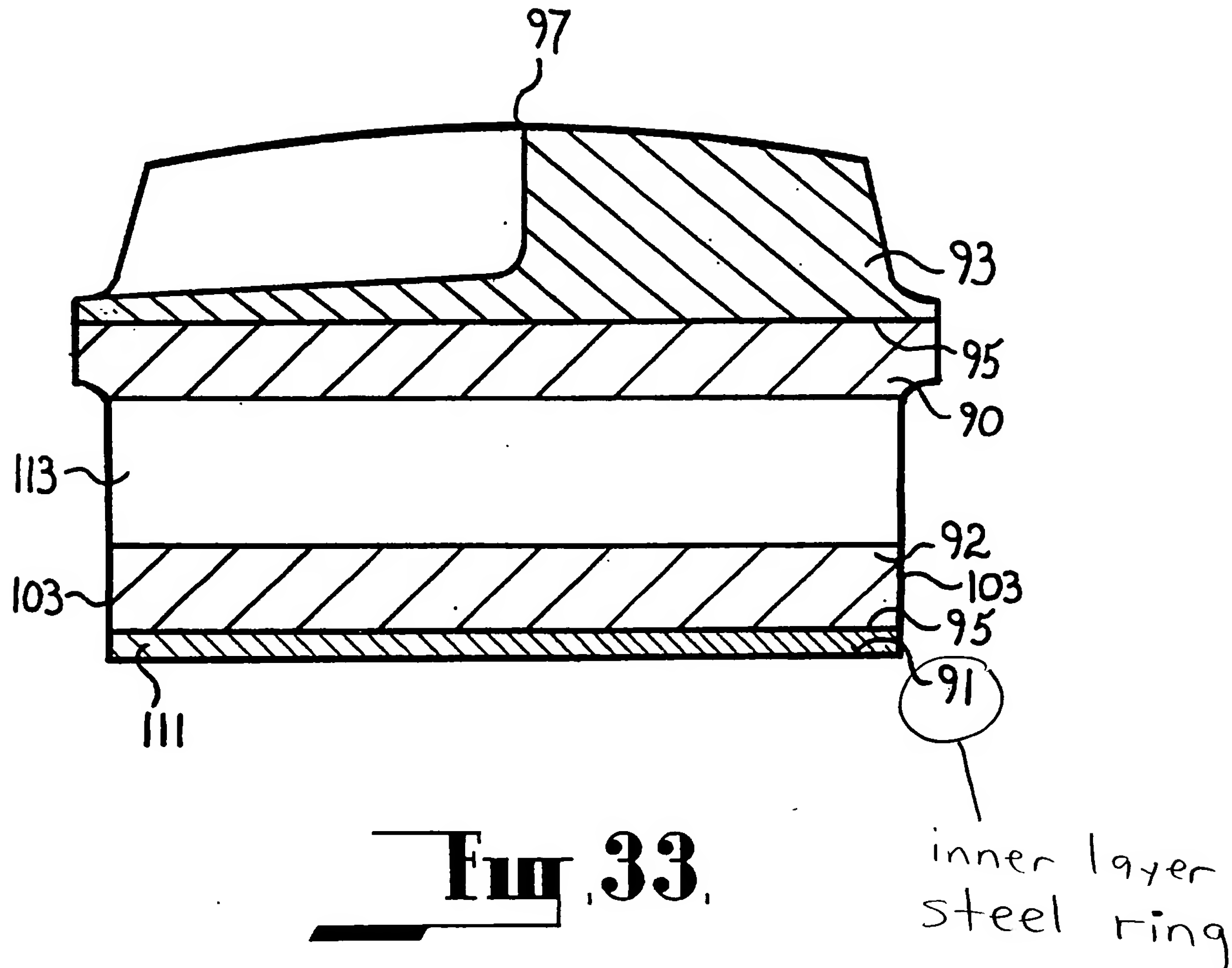


Fig. 33

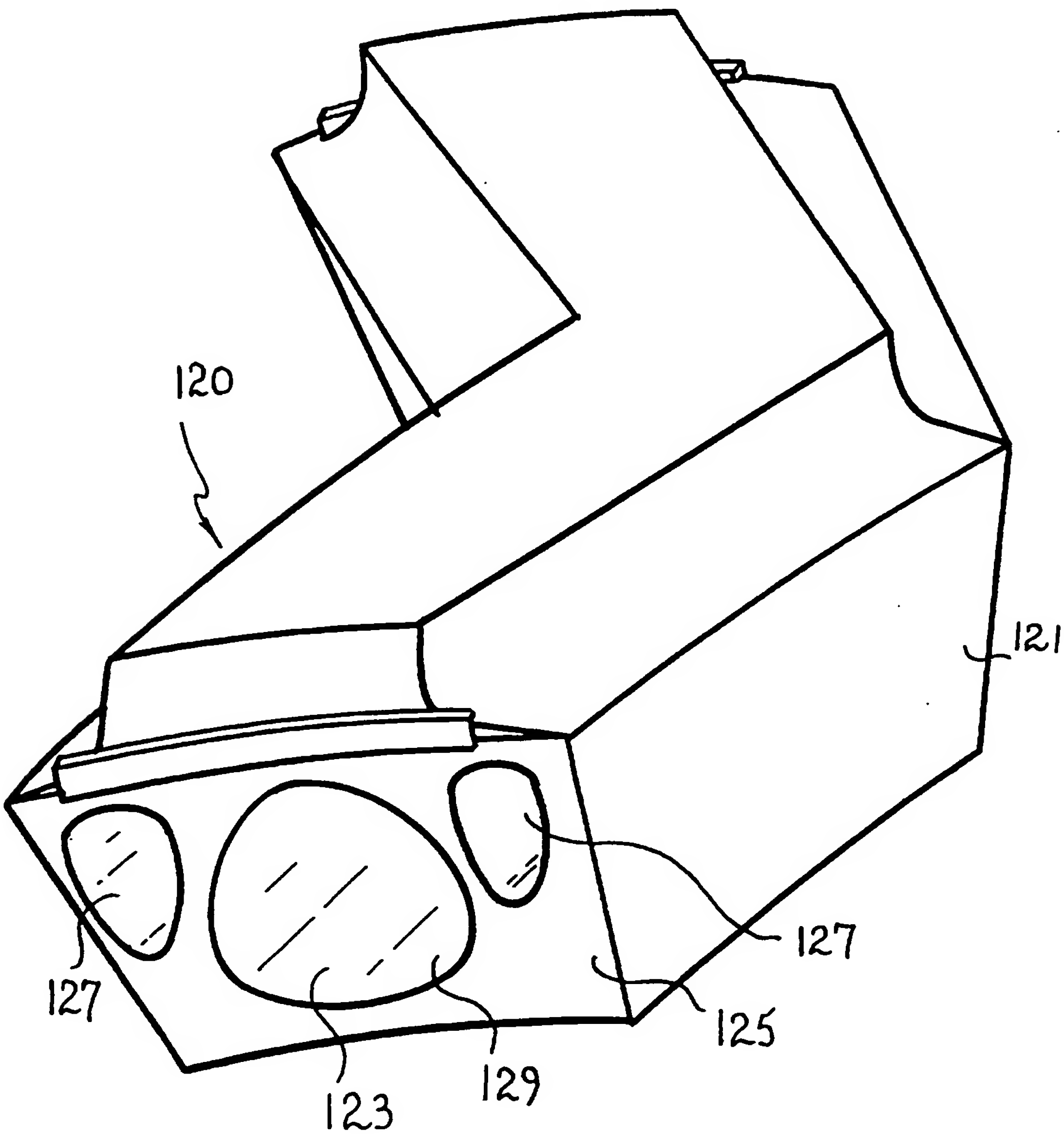


Fig. 34.

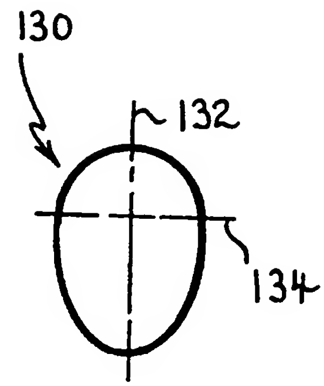


Fig. 35

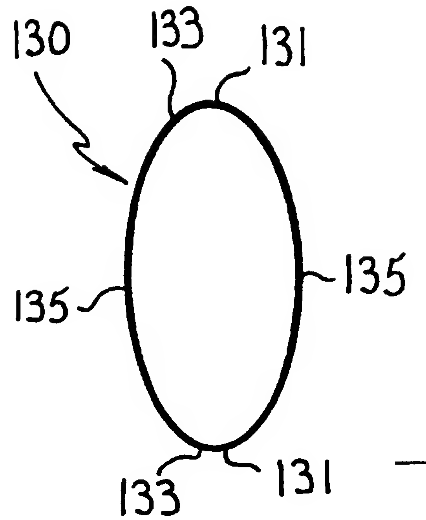


Fig. 36.

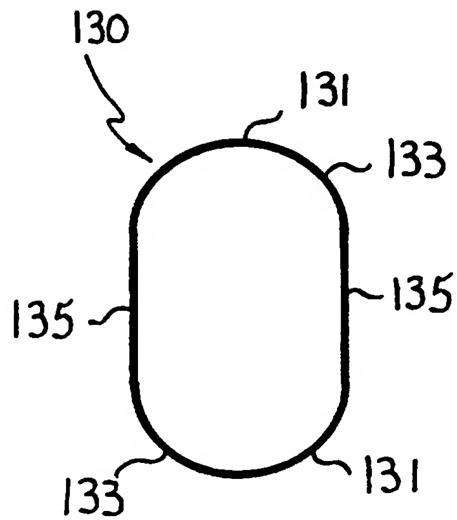


Fig. 37.

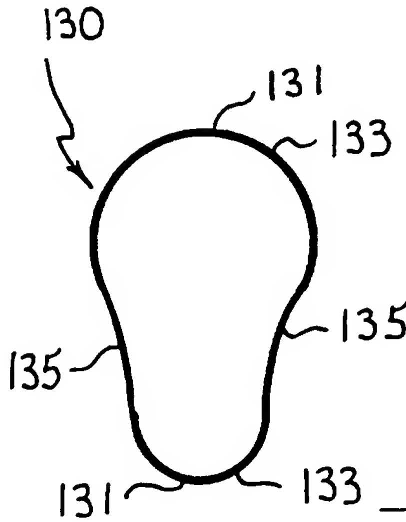


Fig. 38

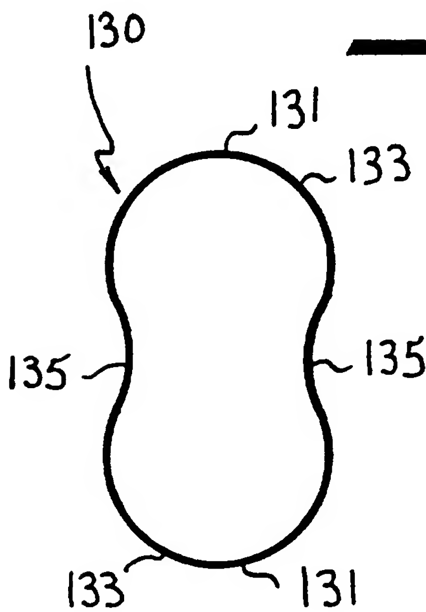


Fig. 39

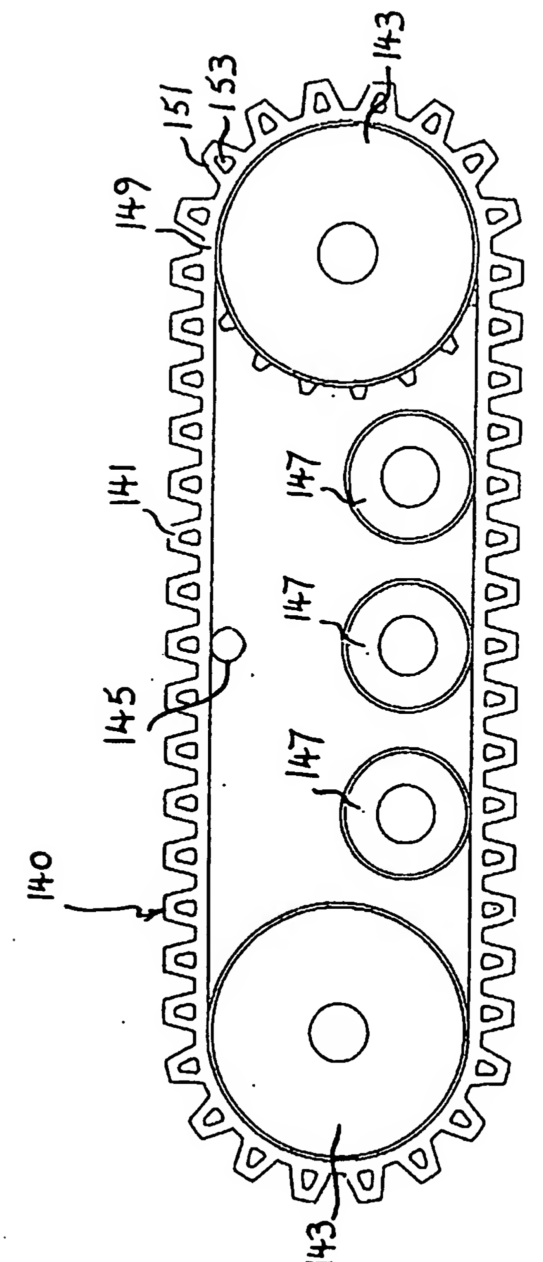


Fig 40

endless track

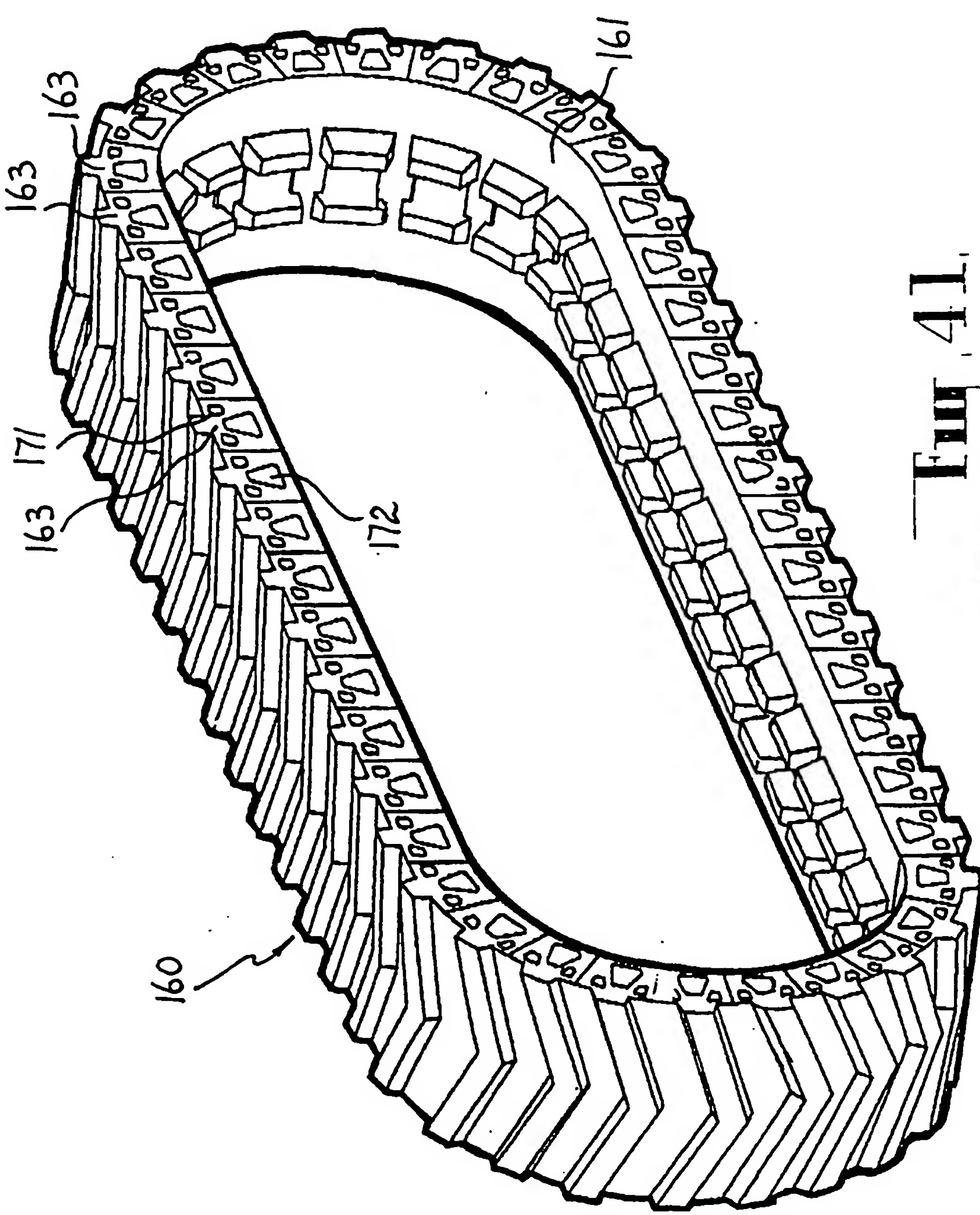


Fig 41

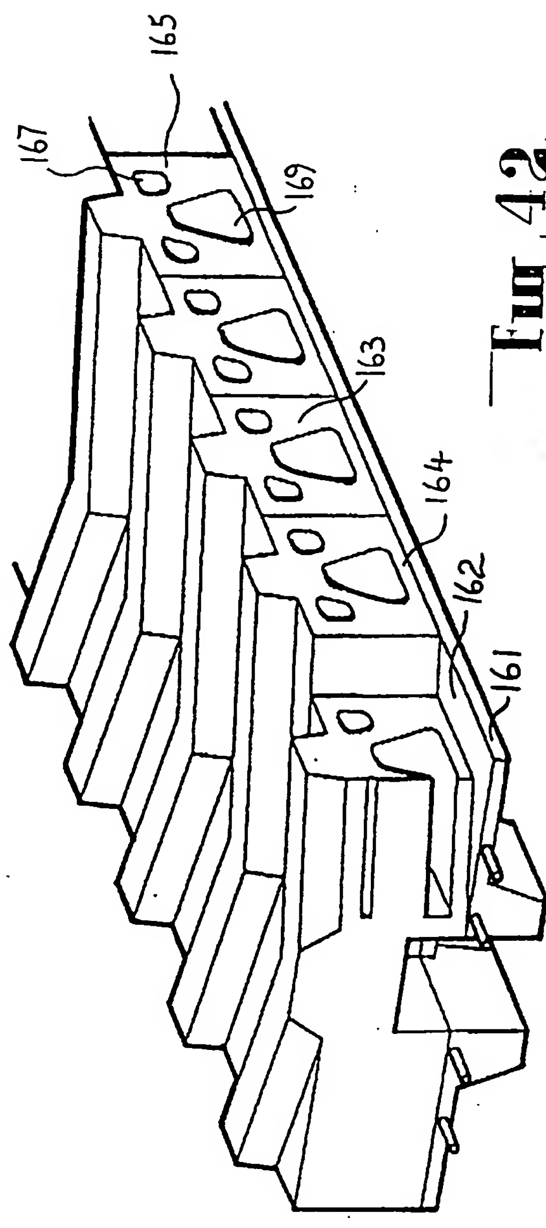


Fig 42

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00514

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: B06C 7/10, 7/08, B62D 55/26, 55/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: B60C 7/10, 7/08, B62D 55/26, 55/24

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 64950/90 A (649630) (ALTRACK LIMITED) 2 May 1991 See Figure 1, item 25	1 to 67, 70 to 81
X	EP 502353 A (THE GOODYEAR TIRE & RUBBER COMPANY) 9 September 1992 See Figure 7 and page 7 lines 33 to 47	1 to 44, 46 to 68, 70 to 79
X	US 1365539 A (PEPPLES) 11 January 1921 See Figures	1 to 44, 46 to 67, 70 to 79

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 1995	6 DECEMBER 1995

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	PETER T. WEST Telephone No.: (06) 283 2108

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 1402947 A (MYERS) 10 January 1922 See Item 5	1 to 44, 46 to 67, 70 to 79
X	US 4945962 A (PAJTAS) 7 August 1990 See Column 6 lines 1 to 24	1 to 44, 46 to 68, 70 to 79
X	FR 581827 A (MOLLOY) 6 December 1924 See Figure 1 and 4, item 3	1 to 67, 70 to 81
P,X	WO 95/03183 A (AIRBOSS LIMITED) 2 February 1995. See page 7 paragraph 5 and Figure 5, item 50	1 to 67, 70 to 81
P,X	WO 95/05947 (AIRBOSS LIMITED) 2 March 1995 See page 10 paragraph 2	68, 69
X	FR 2006313 A (WATTS TYRE & RUBBER COMPANY LIMITED) 26 December 1969 See page 5 paragraph 2	68, 69
X	GB 242459 A (W&A BATES LIMITED) 12 November 1925 See page 1 lines 16 to 28 and page 2 lines 35 to 38	1 to 44, 46 to 68
X	FR 2339504 A (CONTINENTAL GUMMI-WERKE AKTEINGESELLSCHAFT) 26 August 1977 See page 2 paragraph 3	68
X	DE 3134963 A (BAYER AG) 10 March 1983 See Tables	68
X	Derwent Abstract Accession No. 94-206002/25, Class Q11, JP 6-143911 A (OHTSU TIRE & RUBBER CO LTD) 24 May 1994. See whole abstract	68
P,X	Derwent Abstract Accession No. 95-009390/02, Class Q11, JP 6-293203 A (BRIDGESTONE CORP) 21 October 1994 See whole abstract	68

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 95/00514

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Claims 1 to 67 and claims 70 to 80 are directed to ground engaging structures having cavities therethrough. Claims 68 and 69 omit any explicit definition of cavities and are directed instead to a ground engaging structure having layers of material of different hardness. As defined these constitute different "special technical features" and therefore a "technical relationship" as a defined in PCT Rule 13.2 does not exist and the internation application does not relate to a single inventive concept a priori.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International Applicati n N .
PCT/AU 95/00514

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
AU	64950/90						
EP	502353	CA	2043082	JP	5077605	US	5343916
US	4945962	BR	9002719	CA	2016660	EP	401564
		JP	3025004				
WO	9503183	AU	72234/94	IL	110377		
WO	9505947	AU	74535/94	IL	110682		
FR	2006313	BE	731518	DE	1919396	ES	366121
		GB	1262455				
FR	2339504	GB	1573251	JP	52093004		
DE	3134963	EP	74003	JP	58047604		
JP	6143911						
JP	6293203						
							END OF ANNEX